Operative Oral and Maxillofacial Surgery

THIRD EDITION

Edited by

John Langdon • Mohan Patel
Robert Ord • Peter Brennan

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Operative Oral and Maxillofacial Surgery

Third Edition

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To Paul and all those patients from whom I have learnt so much.

JDL

To my wife, Jane, and to my children, Gabriella and Louis. My inspiration and moral compass.

Mo

To my wife Sue, my inspiration as always.

Bob

For Rachel, Ellie, Katie and Rosalind.

Peter

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Preface

Six years have elapsed since publication of the Second Edition of *Operative Oral and Maxillofacial Surgery*. Surgical techniques have continued to advance, and the editors have sought to make this edition as up to date as possible. The use of computers, both in surgical planning and also in the delivery of surgery, is playing an ever more significant role. This is exemplified in the inclusion of chapters on navigational and robotic surgeries. Another topic which has received considerable publicity but is not perhaps mainstream maxillofacial surgery is facial transplantation, and a chapter on this topic is included.

In producing this new edition, the opportunity has been taken to revise, update or rewrite every chapter and to include many new authors. At the same time, readers will notice the inclusion of many more clinical photographs in addition to line diagrams where these have been deemed necessary to illustrate particular details of operative technique.

Some readers might argue that the title of this book no longer represents the scope of the specialty. The editors are well aware of the diversity of titles used by colleagues throughout the world. It could easily be argued that we should change to *Oral and Craniomaxillofacial Surgery* or even *Head and Neck Surgery*. Certainly, thyroid and parathyroid surgery and cranioplasty techniques have historically not sat comfortably within 'maxillofacial' surgery, though many maxillofacial surgeons are involved or even lead in these areas. However, there is no universally accepted comprehensive title that encompasses all the procedures that we practice, and oral and maxillofacial surgery is recognized in most parts of the world, so for this edition, we have remained with it.

John Langdon
Mohan Francis Patel
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This third edition of *Operative Oral and Maxillofacial Surgery* builds on the valuable contributions made by both authors and artists in the previous two editions.

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Chapter 2, **Ultrasound imaging, including ultrasound guided biopsy.** The authors wish to acknowledge Dr. Elisabeth Tilley MRCP, FRCR, Consultant Radiologist, Portsmouth Hospitals NHS Trust.

Chapter 3, **Surgical and other investigations,** contains some material from *Surgical and other investigations* by Julia Woolgar. The material has been revised and updated by the current author.

Chapter 14, **Craniofacial implantology.** The authors wish to acknowledge the contribution made by Southern Implants in the development of the zygomatic oncology and x-type implants.

Chapter 19, **Reconstructive surgery – Harvesting, skin mucosa, bone and cartilage,** contains some material from *Reconstructive surgery – Harvesting, skin mucosa and cartilage* by Peter Ward Booth. The material has been revised and updated by the current author.

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Chapter 35, **Oral and oropharyngeal squamous cell carcinoma: Pathological assessment of resection specimens and neck dissections,** contains some material from *Oral and oropharyngeal squamous cell carcinoma: Pathological assessment of resection specimens and neck dissections* by Julia Woolgar. The material has been revised and updated by the current author.

Chapter 63, **Treatment of temporomandibular joint Ankylosis,** contains some material from *Treatment of temporomandibular joint ankylosis* by Andrew J. Sidebottom and Robert Hensher. The material has been revised and updated by the current author.

Chapter 64, **Total prosthetic replacement of the temporomandibular joint,** contains some material from *Total prosthetic replacement of the temporomandibular joint* by Andrew J. Sidebottom and Robert Hensher. The material has been revised and updated by the current author.

Chapter 65, **Primary closure of the unilateral cleft lip,** has been revised and updated by the current authors.

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Abbreviations

3D	three-dimensional
ABG	alveolar bone grafting
ACF	anterior cranial fossa
ACS	acellular collagen sponge
AFLR	ablative fractional laser resurfacing
AGA	androgenic alopecia
AHI	apnea-hypopnea indices
ALT	anterolateral thigh flap
AMSO	anterior maxillary segmental osteotomy
ANS	anterior nasal spine
ASA	anterior septal angle
ASIS	anterior superior iliac spine
ATLS	advanced trauma life support
AVF	arteriovenous fistula
AVM	arteriovenous malformation
BCC	basal cell carcinoma
BFP	buccal fat pad
BIPP	bismuth iodoform paraform paste
BMP	bone morphogenic protein
BS	bone scan
BSSO	bilateral sagittal split osteotomy
BTMD	bidirectional telescopic mandibular distractor
CAD	computer-aided design
CAM	computer-aided manufacturing
CBCT	cone beam computerized tomography
CCFDAB	crushed cancellous freeze-dried allogeneic bone
CECT	contrast-enhanced computed tomography
CEJ	cemento-enamel junction
CLA	columellar-lobular angle
CLP	cleft lip and palate
CMV	cytomegalovirus
CNC	computerized numerical control
COC	calcifying odontogenic cyst
CPAP	continuous positive airway pressure devices
CRCO	centric relation-centric occlusion
CSA	circumflex scapula artery
CSF	cerebrospinal fluid
CST	cerebral sinus thrombosis
CSV	circumflex scapula vein
CT	computed tomography
CULLP	congenital unilateral lower lip palsy
CW	continuous wave
DCIA	deep circumflex iliac artery
DCP	dynamic compression plate
DICOM	digital imaging and communications in medicine
DIEP	deep inferior epigastric muscle-sparing perforator
DMSO	dimethyl sulfoxide
DO	distraction osteogenesis
DPT	dental panoramic tomogram
DSA	depressor septi nasi
DSA	digital subtraction angiography
DVT	deep vein thrombosis
DWI	diffusion weighted imaging
EBM	electron beam melting
EBV	Epstein–Barr virus
ECA	external carotid artery
ECD	extracapsular dissection
ECG	electrocardiogram
ECS	extracapsular spread
EDS	excessive daytime somnolence
EHL	extensor hallucis longus
ELISA	enzyme-linked immunosorbent assay
EMLA	eutectic mixture of local anaesthetics
ENT	ear, nose and throat
Er:YAG	erbium:yttrium-aluminium-garnet
Er:YSGG	erbium:yttrium-scandium-gallium-garnet
EUA	examination under anaesthetic
EVPOME	ex vivo produced oral mucosa equivalent
FAMM	facial artery musculomucosal
FDA	Food and Drug Administration
FDG	fluoro-deoxyglucose
FHL	flexor hallucis longus
FISH	fluorescent in-situ hybridization
FNA	fine needle aspiration
FNAC	fine needle aspiration cytology
FP	fractional photothermolysis
FUT	follicular unit transplantation
GAF	galea aponeurotica flap
GCR	glenoid fossa-condyle-ramus
GCS	Glasgow Coma Scale
GI	gastrointestinal
HE	haematoxylin and eosin
HPV	human papillomavirus
HRS	hair restoration surgery
HSV	herpes simplex virus
HT	hair transplantation

IADT International Association for Dental Traumatology
IAN inferior alveolar nerve
IANI inferior alveolar nerve injury
ICD inner canthal distance
ICP intracranial pressure
ICU intensive care unit
ID inferior dental
IDC inferior dental canal
IFG invasive front histological multifactorial malignancy grading
IHC immunohistochemistry
IJV internal jugular vein
ImC3c intermediate crus
IMF intermaxillary fixation
IMRT intensity modulated radiotherapy
IPD inter pupillary distance
IPL intense pulsed light
IR infrared
IR(ME)R Ionizing Radiation (Medical Exposure) Regulations
ISH in situ hybridization
ITC isolated tumour cells
KOT keratocystic odontogenic tumour
LBC liquid-based cytology
LLAN levator labii alaeque nasi
LLC lower lateral cartilages
LM lymphatic malformation
M3M mandibular third molar
MCF middle cranial fossa
MDT multidisciplinary team
MIO maximal incisal opening
MMF maxillo-mandibular fixation
MRA magnetic resonance angiography
MRI magnetic resonance imaging
MRND modified radical neck dissection
MSCT contemporary multislice computed tomography
MTA mineral trioxide aggregate
NAFR non-ablative fractional resurfacing
NALR non-ablative laser resurfacing
NCA nurse-controlled analgesia
NFA nasofrontal angle
NHL non-Hodgkin lymphoma
NICE National Institute of Clinical Excellence
NIM neural integrity monitor
NOE naso-orbital ethmoidal
NSF nephrogenic systemic fibrosis
OAF oro-antral fistula
OCD outer canthal distance
OCS orbital compartment syndrome
OF occipito-frontal
OFG orofacial granulomatosis
OGD oesophagogastroduodenoscopy
OKC odontogenic keratocyst
OM occipitomental
OMFS oral and maxillofacial surgery
OPG orthopantomogram
OPT orthopantomogram
ORIF open reduction and internal fixation
OSCC oropharyngeal squamous carcinoma
PA posteroanterior
PACS picture archiving and communication system
PAS periodic acid Schiff
PCR polymerase chain reaction
PDL periodontal ligament
PDL pulsed-dye lasers
PDS polydioxanone
PEEK polyether ether ketone
PEG percutaneous endoscopic gastrotomy
PET positron emission tomography
PF posterior fossa
PFL palpebral fissure length
PMSO posterior maxillary segmental osteotomy
PRF palatal rotation flap
PRP platelet rich plasma
PSA posterior septal angle
PT prothrombin
PTE pulmonary thromboembolism
PTT partial thromboplastin times
PVA polyvinyl alcohol
RAPD relative afferent pupillary defect
RBH retrobulbar haemorrhage
RCT randomized controlled trial
RDI respiratory distress index
RED rigid external distraction
RFFF radial forearm free flap
RND radical neck dissection
ROOF retro-orbicularis fat
RPM rapid prototyping modelling
RSTL relaxed skin tension lines
RTD residual thermal damage
SCC squamous cell carcinomas
SCM sternocleidomastoid muscle
SLM selective laser melting
SLS selective laser sintering
SMAS superficial muscular aponeurotic system
SMV submental vertex
SNA sella-nasion-A
SND selective neck dissection
SOHND supra-omohyoid neck dissection
SORG Strasbourg Osteosynthesis Research Group
SP superficial parotidectomy
SPECT single photo emission computed tomography
SRS stereotactic radiosurgery
SSTE skin soft tissue envelope
STB supra tip break
STL surface tesselation language
STSG split-thickness skin graft
TCA transverse cervical artery
TF temporalis fascia
TI transfixion incision
TIG tetanus immune globulin
TM temporomandibular
TMF temporalis muscle flap

TMJ temporomandibular joint
TNM tumour node metastasis
TORS transoral robotic surgery
TP tip projection
TPA trans-palatal arch
TPFF temporoparietal fascial flap
TR tip rotation
TRAM transverse rectus abdominis myocutaneous
TUG transverse upper gracilis
UICC International Union Against Cancer
ULC upper lateral cartilages
UPPP uvulopalatopharyngoplasty
US ultrasound
VA vertebral artery
VM venous malformation
VPD velopharyngeal dysfunction
VPI velopharyngeal insufficiency
VRAM vertical rectus abdominis myocutaneous

SECTION I

DIAGNOSTIC INVESTIGATIONS

1

Imaging techniques, including computed tomography-guided biopsy and fluorodeoxyglucose-positron emission tomography

STEVE CONNOR

CONTENTS

INTRODUCTION

Maxillofacial imaging has evolved in parallel with the development of newer imaging technologies. Traditional plain radiography and dental imaging are now frequently supplemented by cross-sectional modalities such as computed tomography (CT), magnetic resonance imaging (MRI) and ultrasound, together with functional imaging modalities such as positron emission tomography (PET). It is important to be aware of the benefits and limitations of such imaging examinations as they are applied to the appropriate clinical scenario.

RADIATION PROTECTION

Some imaging investigations use ionizing radiation which has the potential to result in biological damage. The aim of radiation protection is to provide a safe environment for the worker and patient. The Ionizing Radiation (Medical Exposure) Regulations 2000 (IRMER) lays down basic measures required for protection against the harmful effects of medical radiation exposure. There were minor amendments to this legislation in 2006 and 2011. There are duties of the 'employer' who provides a framework within the area where the exposures take place, the 'operator' who carries out the exposure, the 'practitioner' who justifies the exposure and the 'referrer' who request the exposure. Key principles are that (1) the examination should be of sufficient benefit to justify radiation exposure, (2) dose is optimized by the ALARA (As Low As is Reasonably Achievable) principle and (3) dose limits should be recorded.

PLAIN RADIOGRAPHS

X-rays are produced by a point source and, after passing through the body part of interest, are detected by non-screen (dental radiography) or intensifying screen/film combinations (extraoral radiography). Selected facial radiographic views are listed in Table 1.1. Tomography refers to a technique whereby the x-ray source and film move during the exposure. The aim is to demonstrate only a 'section' which is in focus whereas structures outside this section are blurred. Applications include conventional

Table 1.1 Radiographic views of the facial skeleton.

	Radiographic view	Comment
Mid and upper third	Occipito-frontal (OF) 15–20 (Caldwell view)	Used to visualize upper third of face
	OF 25 (modified Caldwell view)	Superior visualization of orbital floor relative to Caldwell view
	Occipito-mental (OM)	Used to visualize mid-third of the face
	OM 10	Less obscuration of maxillary antrum than an OM view
	OM 30	Superior view of malar arches and inferior orbital margins Preferable to submentovertical (SMV) view
		Supplementary for central midface injury
Lower third	Lateral	Replaces OPG if not available or impractical
	Postero-anterior (PA) mandible	Better visualizes mandibular condyles
	Lateral oblique	
	Reverse Towne's	
	Orthopantomogram (OPG)	

dental panoramic tomography, tomograms of the temporomandibular joints and mandibular tomograms for implant planning.

Digital radiography units (using digital receptors to intercept the x-ray beam rather than intensifying screens) are now replacing conventional units. This allows transmission of data to image processing and storage devices as well as communications networks.

CONTRAST STUDIES

Contrast media may be introduced into a vessel, lumen or cavity in order to render it radio-opaque and hence radiographically visible. This may then be viewed 'real time' with fluoroscopic imaging or with serial radiographs. Contrast media used for this purpose include barium sulphate suspensions and non-ionic iodinated contrast agents. There is a small risk associated with the intravascular iodinated contrast agents which must be weighed against the potential benefits. Information which should be sought from the patient before contrast injection includes previous contrast reactions, asthma, renal problems, diabetes and metformin therapy.

Contrast studies with maxillofacial applications are as follows:

1. *Angiography:* Conventional angiography is generally performed as a precursor to interventional radiological techniques. CT and magnetic resonance (MR) angiography have largely replaced diagnostic applications in maxillofacial pathology. It remains appropriate for the planning of embolization of high-flow vascular malformations and tumours (Figure 1.1) and for the evaluation of arterial injury (traumatic or tumour erosion). Angiographic catheters are generally introduced over a guidewire via a common femoral artery puncture. Small calibre microcatheters may be introduced into distal external carotid artery branches.
2. *Barium/contrast studies:* Contrast swallows, with barium or iodinated contrast medium, may be required to evaluate for high dysphagia and pain or for postoperative anatomotic leaks. Rapid serial radiography or video recording may be used to assess the hypopharynx and upper oesophagus during deglutition (Figure 1.2). Barium may be combined with a gas-producing agent and an intravenous smooth muscle relaxant to produce 'double-contrast' images of the lower oesophagus. If aspiration or tracheo-oesophageal fistulation is suspected, then a low osmolar iodinated contrast medium will be used.
3. *Sialogram:* Iodinated contrast medium may be introduced into the salivary duct ostium via a polythene catheter. Fluoroscopy or radiography is used including delayed images after administration of a sialagogue. This is compared with preprocedure 'control' films.

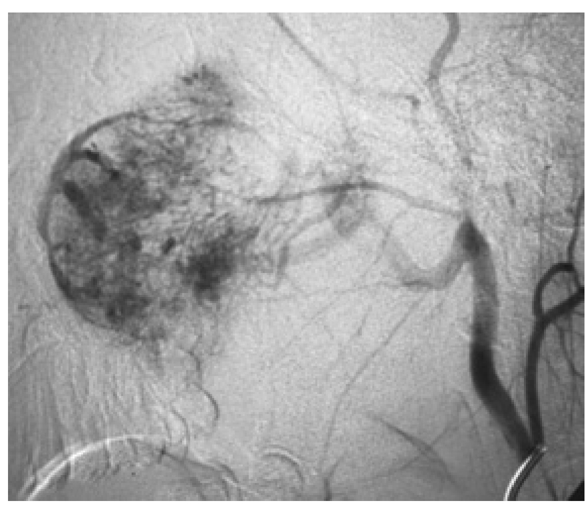


Figure 1.1 Lateral projection in the arterial phase of a common carotid angiogram demonstrates a vascular blush arising from the maxillary artery secondary to a juvenile angiofibroma.

Figure 1.2 Oblique projection of a barium swallow demonstrates a pharyngeal pouch (white arrowhead).

4. *Sinogram/fistulogram:* A sinogram involves the insertion of a fine catheter into the orifice of a sinus and injection of contrast medium to delineate a sinus or fistula. If there is a complex tract then it may be combined with CT.
5. *TMJ arthrogram:* Iodinated contrast medium is injected into the joint under fluoroscopic guidance and double-contrast studies may be achieved by contrast withdrawal and replacement with air, although this is now rarely performed.
6. *Dacrocystogram:* The nasolacrimal sac and duct may be cannulated and injected with contrast medium in patients with epiphora. The lacrimal drainage system may also been evaluated with CT and MRI following conjunctival application of contrast medium.
7. *Percutaneous venogram:* Percutaneous venography may be used as a precursor to sclerotherapy for the assessment of volume and venous 'run off' in the sitting of low-flow venous malformations. A similar technique (lymphogram) is used for a lymphatic malformation. Ultrasound is used to guide the needle placement if the lesion is not clinically palpable.

COMPUTED TOMOGRAPHY

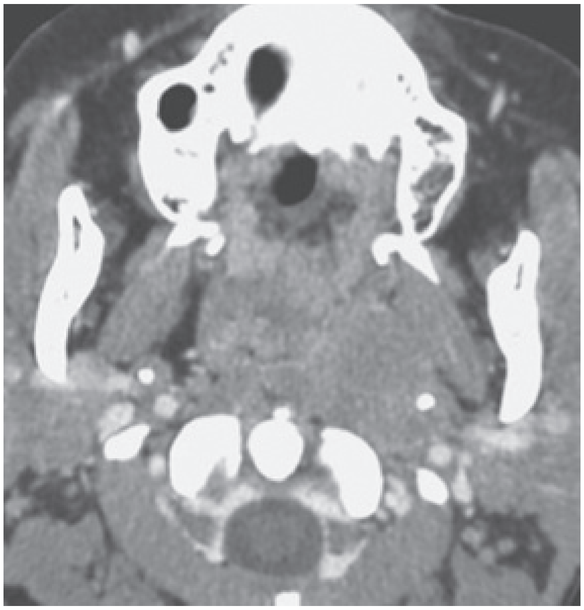
CT is an imaging modality which is rapid and widely available. A CT scanner consists of an x-ray tube which sends a fan of x-rays through the patient and the attenuation of the beam by the patient is detected. The process is repeated as the tube and detectors rotate and the patient is advanced through the scanner. The degree of x-ray absorption by each volume of tissue (voxel) is displayed as a pixel which is allocated a number (Hounsfield unit) (Table 1.2). This information may be digitally manipulated so as to best demonstrate the tissues of interest (e.g. by changing the range of 'numbers' in the grey scale or 'window width' or by using algorithms to alter the 'sharpness' of the image). The same information may be used to provide multiplanar reformats or rendering of three-dimensional (3D) objects to facilitate visual assessment. Imaging of soft tissues generally requires the administration of iodinated contrast medium to enhance pathological tissues and help delineate vascular structures from other soft tissue such as lymph nodes. Artefact from metallic materials such as dental restoration may markedly degrade imaging of the face due to 'beam-hardening artefact'; however, there are methods to reduce this, such as specific angling of the scan plane or the use of specific image reconstruction techniques. The availability of CT fluoroscopy and 'in room' CT controls/monitors has improved the safety and efficacy of CT-guided biopsies of deep facial and skull base lesions (Figure 1.3).

Table 1.2 Hounsfield units (attenuation) of tissues.

	Typical hounsfield units	Computed tomographic appearance
Air	–1000	Black
Fat	–50 to –100	
Water	0	
Soft tissue	+30–50	
Acute blood	+50–80	
Bone	+1000	White

Contemporary multislice computed tomography (MSCT) differs in that a number of slices are obtained per tube rotation. Current scanners are typically 64 slices with 256 or 320 slices being used for some applications. MSCT has the potential to scan standard volumes with shorter acquisition times so reducing movement artefact (e.g. due to swallowing) or requirement for sedation and optimizing vascular opacification (e.g. for CT angiographic studies) (Figure 1.4). It also allows the scanning of larger volumes or the use of narrower section thickness (as low as 0.3–0.5 mm) so optimizing the 3D data set for post-processing and interactive 3D image–guided surgery. The large number of images generated by MSCT potentially impacts on workstation performance and picture archiving and communication systems (PACS) archiving/networking.

The benefits of CT (Table 1.3) should always be weighed against the risks of ionizing radiation exposure. Whilst imaging of soft tissues requires higher radiation doses and hence strong clinical justification (typical effective dose for brain CT is 2 mSv which is equivalent to 100 chest radiographs or 10 months of natural background radiation), low-dose imaging focused on bony detail (e.g. 'dental CT' for implantology) may be performed with 0.2–0.3 mSv whilst 3D cephalometric bone landmarks may be identified at doses approaching a radiographic series.



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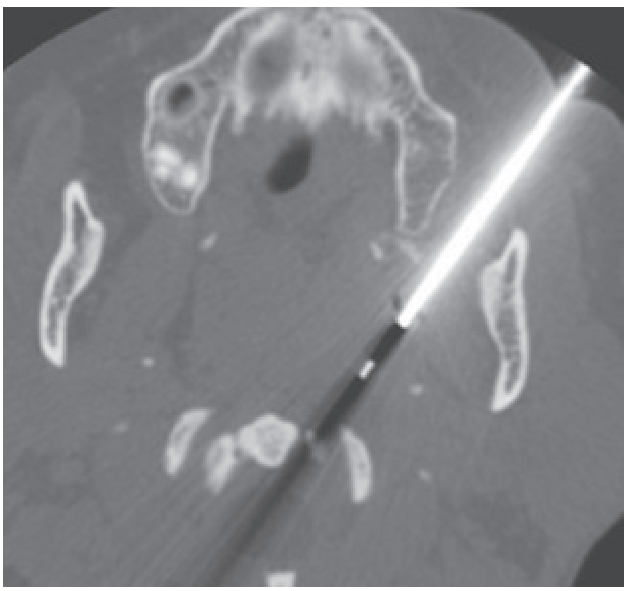


(b)

Figure 1.3 (a) Computed tomography (CT) displayed with soft-tissue windows demonstrates a preclival abscess and central skull base destruction resulting from tuberculous osteomyelitis. (b) CT displayed with bone windows delineates the core biopsy needle within the abscess.

Manufacturers have developed various dose reduction techniques on contemporary CT scanners.

Cone beam computed tomography (CBCT) has developed as a technique which provides high-resolution 3D data at low-radiation doses (e.g. equivalent to 2–8 OPGs). The equipment may resemble that of a conventional dental panoramic tomography unit (patient erect) or may mimic a conventional CT scanner (patient supine). A cylinder- or sphere-shaped volume of data is rapidly acquired with a single tube rotation. Some CBCT equipment is designed to

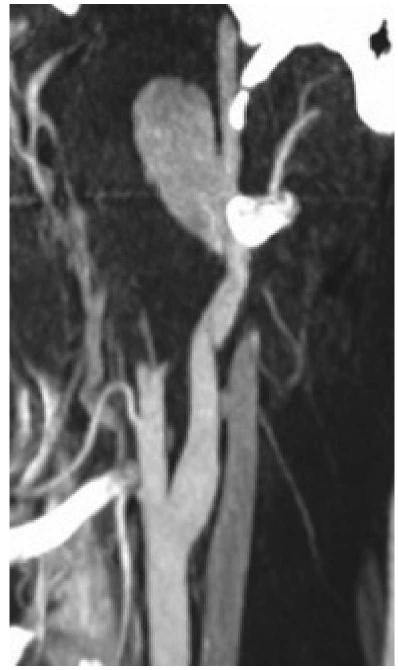


Figure 1.4 Lateral maximum intensity projection of a CT angiogram demonstrates a post-traumatic pseudoaneurysm of the internal carotid artery.

Table 1.3 Advantages and disadvantages of computed tomography (CT) and magnetic resonance imaging (MRI).

	CT	MRI
Advantages	Widely available Rapid so less prone to movement artefact Demonstrates cortical bone and calcification well May be combined with imaging of the lungs Excellent spatial resolution and 3D post-processing	Does not require ionizing radiation Usually less image distortion than CT from metallic foreign bodies Delineates bone marrow pathology well (e.g. mandible/central skull base) Superior for skull base and intracranial imaging Excellent contrast resolution with direct multiplanar imaging
Disadvantages	Ionizing radiation May require iodinated contrast media (incidence of severe reactions is 0.04%)	Absolute contraindications preclude some patients Claustrophobia precludes some patients Time consuming and prone to motion artefact if patient breathless/unwell Expensive

simulate intraoral radiographs by imaging small volumes (e.g. two to three teeth) at high resolution, whilst other equipment is designed to image the whole maxillofacial region (e.g. 15 cm^3 spheres). The low tube currents utilized to reduce the radiation dose unfortunately preclude adequate imaging of soft-tissue structures. Evidence-based guidelines for the use of CBCT in dental and maxillofacial radiology have been produced by the SEDENTEXCT project (www.sedentexct.eu/files/guidelines_final.pdf).

MAGNETIC RESONANCE IMAGING

MRI does not require ionizing radiation so should be preferred in cases where it would provide similar information to CT and both are available. Advantages and disadvantages relative to CT are shown in Table 1.3. There are contraindications to the use of MRI including metallic foreign bodies in the orbit as well as many intracranial aneurysm clips, cardiac pacemakers and cochlear implants. There is guidance from manufacturers and additional third-party testing of many medical devices, implants and materials and they are classified as 'safe', 'conditional' (no known hazard in a specified MRI environment under specified conditions) or 'unsafe'.

The MRI signal is tissue dependent and is based on the behaviour of protons within the tissue when they are exposed to radiofrequency pulses within a magnetic field. Signal can be resolved into two components (T1 and T2). Selecting appropriate pulse sequences allows images to reflect the T1-weighted (T1-w) or T2-weighted (T2-w) characteristics of tissues. Most pathology results in increased water content relative to normal tissues and thus is shown as decreased signal on T1-w images and increased signal on T2-w images (Figure 1.5). There are various other tissues and substances which may be distinguished by differing MRI signal (Table 1.4). MRI contrast enhancement may be achieved with gadolinium-based agents. Patients requiring gadolinium are evaluated for the presence of severe renal insufficiency as there is a rare association with nephrogenic systemic fibrosis (NSF). Pre- and post-gadolinium (contrast medium) sequences should be performed with T1-w. T1-w sequences may also be combined with fat saturation post-gadolinium such that increased signal due to enhancement is not masked by that due to fat. Pathological lesions undergo variable enhancement and gadolinium is used to help characterize lesions. Normal structures that markedly enhance include mucosal linings and lymphoid tissue. The short-time inversion recovery (STIR) sequence has been shown to be very sensitive to pathology which generally demonstrates increased signal. Multiplanar imaging (coronal and axial imaging as a minimum) is routinely performed with 4–5 mm section thickness. There is continued improvement in the diagnostic quality of volumetric sequences which are likely to be increasingly used.

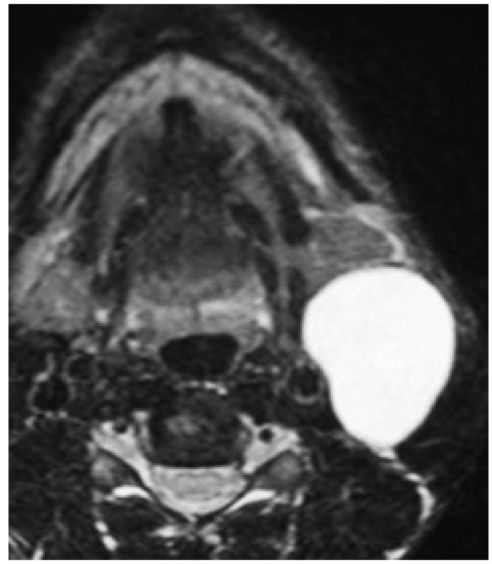


Figure 1.5 Axial T2 weighted fat saturated magnetic resonance imaging (MRI) shows a T2 hyperintense left second branchial cleft cyst.

Typical imaging sequences for a study of the face and neck would include T1-w axial, T2-w axial, T1-w post-gadolinium axial, STIR coronal and T1 fat saturated post-gadolinium coronal images. Diffusion weighted imaging (DWI) is also a routine sequence in many centres, and has a developing role, being particularly useful in the assessment of post-chemoradiotherapy residual tumour.

MR angiography may demonstrate flow in relation to a vessel lumen with or without the use of gadolinium. Other MRI techniques (such as spectroscopy, diffusion and perfusion imaging), higher field magnets (3 T as opposed to standard 1.5 T) and novel contrast agents, have been applied to the face and neck although clinical utility is not yet established.

Table 1.4 Magnetic resonance imaging characteristics of tissues relevant to face and neck MRI.

Signal	Substrate
High T1-w signal	Proteinaceous secretions, fat, gadolinium enhancement, subacute haemorrhage, slow flowing blood (e.g. veins)
Low T1-w signal	Most pathology (note: pathology generally intermediate to low T1-w signal)
High T2-w signal	Most pathology (note: cellular tumour is intermediate T2-w signal, whereas necrosis/cyst/inflammatory paranasal mucosal thickening is markedly increased T2-w signal)
Low T2-w signal	Mature fibrosis/scar, very dense proteinaceous secretions, acute haemorrhage
Signal void (very low T1-w and T2-w)	Cortical bone and dense calcification, air, fast flowing blood

POSITRON EMISSION TOMOGRAPHY AND OTHER RADIOISOTOPE IMAGING

PET differs from the previously mentioned anatomical techniques in that it provides functional imaging of metabolic activity. This has proved very useful in the setting of maxillofacial malignancy (Figure 1.6) with improved diagnostic accuracy relative to CT and MRI. Most PET imaging studies of the head and neck use the short-lived radiotracer 18-fluorodeoxyglucose (^{18}FDG) which allows an examination of altered glucose metabolism as a marker of tumour activity. This unstable radioisotope releases a positron over a short distance after which it annihilates with an electron and emits the photons that are detected. This process of photon production implies a lower limit of spatial resolution (3–4 mm) so PET does not provide the same anatomical detail as CT or MRI. To improve the localization of pathology, PET images were initially co-registered with CT or MR images; however, techniques have now progressed such that functional and anatomical CT images (PET-CT), and now MRI images (PET-MR) may be obtained on the same scanner.

It should be noted that the CT component of such PET-CT scanners may be performed without contrast medium and does not generally use the same parameters as diagnostic CT so it may not be a direct substitute. Multiple slices are obtained and multiplanar reformats are routine. A dedicated head-and-neck field view may be followed by a separate half-body study. PET-MR is only currently available at a few centres and its exact role in maxillofacial imaging is yet to be defined.

PET must be interpreted with an awareness of the limitations in detecting small volume (particularly <3–4 mm) disease, including superficial mucosal lesions, lymph node micrometastases and necrotic lymph nodes. Some tumours such as salivary gland tumours are not ^{18}FDG avid. Some centres use an objective measure of FDG uptake (SUV) to help distinguish a malignant lesion. There are also pitfalls due to false-positive findings resulting from normal tracer distribution (e.g. salivary and thyroid gland, muscle activity and Waldeyer's ring) and inflammatory tissue (e.g. lymph nodes, early stages post-tumour treatment and healing bone).

Other radioisotopes used in the investigation of maxillofacial disease include the following:

1. ^{99m}Tc-MDP for the evaluation of bone disease (e.g. condylar hyperplasia, degree of activity in fibroosseous lesions, bone metastases, bone invasion by tumour, osteomyelitis, integrity of blood supply in radionecrosis or vascularized grafts).
2. ^{111}Indium-labelled and ^{99m}Tc-HMPAO-labelled leukocytes together with ^{67}Ga-gallium citrate for the diagnosis and localization of infection or inflammation in soft tissues.
3. ^{99m}Tc-pertechnetate for dynamic salivary gland imaging or to detect ectopic thyroid tissue.

PICTURE ARCHIVING AND COMMUNICATION SYSTEMS

PACS is a technology which enables the storage and archiving, retrieval, secure networking and display of imaging studies. It overcomes the difficulties of manually storing and reviewing traditional hard copies. The universal format for PACS image storage and transfer is DICOM (Digital Imaging and Communications in Medicine). Additional advantages of PACS are the ability to access remotely, to help manage workflow and to interact with other systems (e.g. radiology information systems).

IMAGING IN DIFFERENT CLINICAL SCENARIOS

Tables 1.5 through 1.16 provide information on imaging in different clinical scenarios.

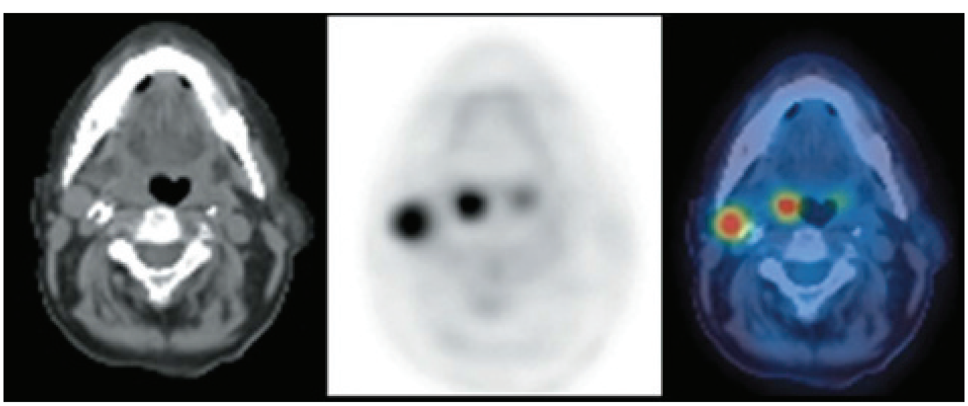
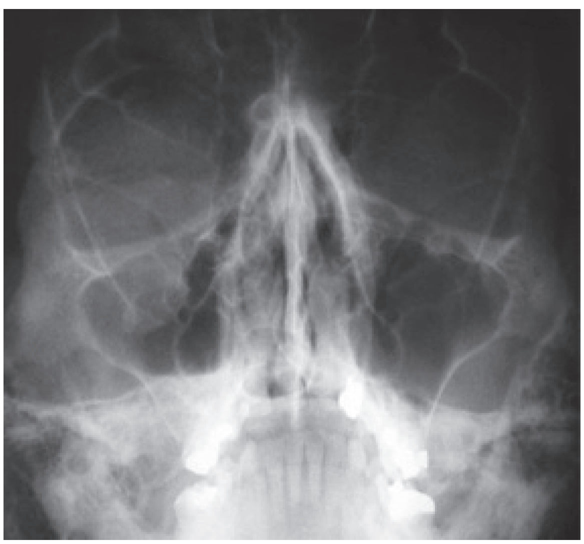


Figure 1.6 Axial sections of a positron emission tomography–computed tomography (PET-CT) study: CT (left), PET (middle), fused PET-CT (right). Patient presented with a right level 2 lymph node and an unknown primary tumour. 18-Fluorodeoxyglucose (^{18}FDG) uptake is demonstrated within the lymph node and related to a right tonsilla fossa primary carcinoma. Note the physiological uptake within the left-sided tonsillar tissue.

Table 1.5 Imaging of craniofacial malformations and craniosynostosis.

Imaging modality	Imaging issues	Comment
Radiographs: Standard mid-facial series is OM, OM 15/30 and lateral Standard mandibular series is OPG (lateral obliques if not available/impractical) and frontal	Screen for fractures and assess need for further CT	Most uncomplicated zygomatic, orbital and mandibular injuries may be evaluated with plain radiography alone Single midface views (OM or OM 30) are acceptable for screening for significant midface fractures (Figure 1.7)
Low-dose CT with 3D post-processing Standard CT	Delineate extent and displacement of fractures Review key sites e.g. displaced fractures of frontal sinus posterior wall	Always consider intracranial and cervical spine imaging in the early management of high energy facial injury CT is also required for suspected craniofacial injury or when there is orbital dysfunction (Figure 1.7), fractures are severe/comminuted or as a precursor to surgery Standard (non–low dose) CT may be used to evaluate orbital or cranial soft-tissue complications 3D data set post-processing may be used for modelling of implants and to aid surgical planning in patients with complex fracture geometry (Figure 1.8)
MRI	Soft-tissue (including intracranial) complications	
Others: ocular ultrasound, dacrocystography, sialography, CT cisternography	Soft-tissue complications	Selected cases depending on clinical findings



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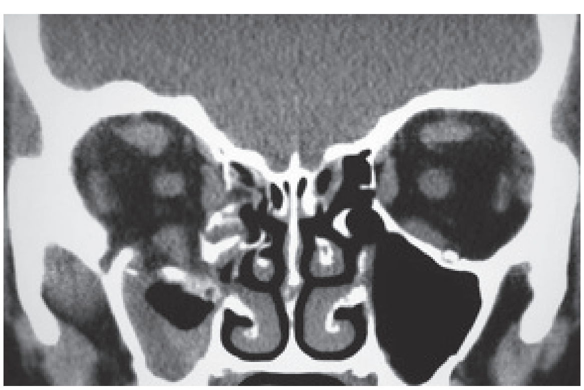


(b)

Figure 1.7 (a) Occipito-mental (OM) view demonstrates a right orbital floor fracture with soft tissue prolapsing into the maxillary antrum and a fluid level. (b) Coronal CT study in a patient with an orbital floor fracture and persistent diplopia reveals prolapse of orbital fat and distortion of the inferior rectus muscle.

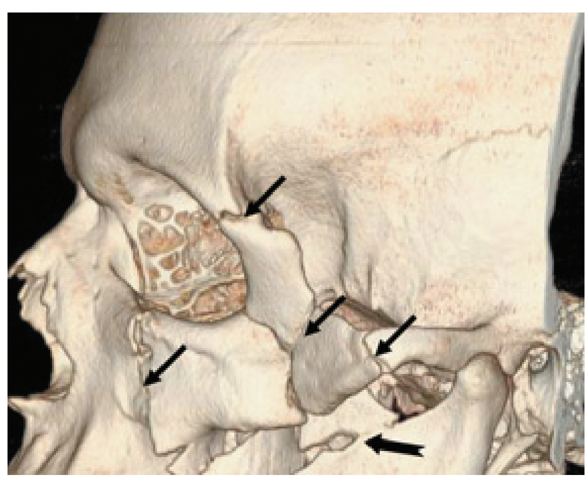


Figure 1.8 Volume-rendered lateral projection of a 3D CT data set. There is a comminuted left zygomatico-maxillary fracture (arrows).

Table 1.6 Imaging of facial/craniofacial trauma.

Imaging modality	Imaging issues	Comment
Radiography: OPG, cephalometry, skull series		Isolated sagittal, metopic or unilateral coronal synostosis may be confirmed with radiography
Low-dose CT 3D data (cranial or craniofacial) with post-processing	Define foci of sutural synostosis for surgical planning 3D assessment of facial deformity and orofacial clefts	CT with post-processing is more definitive and superior for defining foci of sutural closure. Required for surgical planning and for assessment of complex craniofacial anomalies/petrous temporal bone anomalies 3D data set may be used for pre-operative surgical stimulation with stereolithography or fused deposition modelling
Cranial CT/CTV /MRI	Detect intracranial malformations and venous stenosis in the setting of complex synostosis	

Table 1.7 Imaging of facial vascular malformations.

Imaging modality	Imaging issues	Comment
Ultrasound	Extent Characteristics of high or low flow vascular malformation/tumours	Ultrasound imaging of choice for assessing superficial lesions
MRI		MRI better for assessing deep extent and for further characterization of lesions
Conventional angiography +/– embolization	Assess arterial feeders and extra/intracranial arterial connections prior to embolization	For assessment and potential embolization of high flow arteriovenous malformations/fistulae and tumours (alone or as precursor to surgery)
Percutaneous venography/lymphography with sclerotherapy	Assess venous drainage and volume of malformation prior to sclerotherapy	For assessment and sclerotherapy (STS, alcohol) of low-flow venous malformations and lymphangiomas

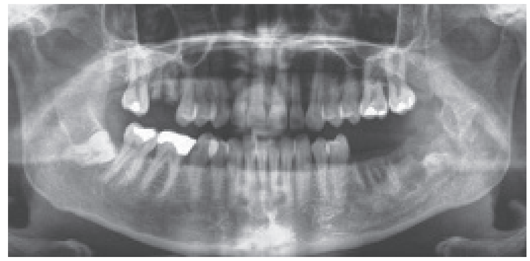
Table 1.8 Imaging of facial and neck infection.

Imaging modality	Imaging issues	Comment
Radiographs		Radiographs to assess for dental disease
CT (contrast enhanced) MRI (gadolinium enhanced)	Distinguishing abscess from phlegmon Disease extent Vascular compromise Infection source	Contrast-enhanced CT and gadolinium-enhanced MRI equivalent for assessing phlegmon versus abscess (Figure 1.9) CT superior for assessingassociated mandibular cortical erosion and salivary gland calculi

Table 1.9 Imaging of mandibular osteomyelitis.

Imaging modality	Imaging issues	Comment
Radiography	Confirm diagnosis and exclude other lesions Response to treatment	OPG helpful for assessing dentition and predisposing conditions such as fractures or systemic bone disease Appropriate for follow up (Figure 1.10)
MRI (thin section)	Low T1-w with gadolinium enhancement and increased short-time inversion recovery (STIR) signal corresponds to active infection in the medullary cavity	MRI should be primary cross sectional imaging for acute and chronic osteomyelitis
CT	Osteolysis in the acute phase with subsequent periosteal reaction Sclerosis sequestration in subacute/chronic osteomyelitis	CT superior for detecting the degree of cortical destruction, presence of sequestra and the degree of cortical removal that would be required (Figure 1.10) Maybe used as an adjunct particularly prior to surgery
Radioisotope	Multifocal disease	Lacks the anatomical detail for surgical planning

Figure 1.9 Axial contrast-enhanced CT section reveals ring enhancing abscesses (arrows) within the left masticator space including the left submasseteric region.



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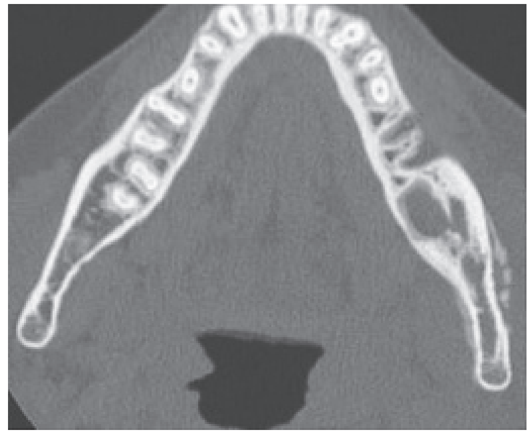


(b)

Figure 1.10 (a) Orthopantomogram (OPG) and (b) axial CT section imaged on bony windows. There are medullary lysis, cortical irregularity and sequestration related to left subacute mandibular osteomyelitis.

Table 1.10 Imaging of maxillofacial malignancy.

Imaging modality	Imaging issues	Comment
CT (contrast enhanced)	Primary tumour extent Imaging detects submucosal extension to correlate with mucosal inspection Key issues depend on subsite and include bone invasion (e.g. mandible), neurovascular involvement, midline extension, perineural extension, orbital and skull base involvement Expect spurious changes if performed within 10–14 days of biopsy Nodal metastases (especially if outside area of intended neck dissection and for radiotherapy planning) Distant metastases or synchronous primary tumours	CT preferred: • If CT chest also required • In very unwell or elderly patients • If MRI contraindications or • If obscuring dental amalgam
MRI (gadolinium enhanced)		MRI preferred • For salivary gland tumours • Any potential skull base or intracranial involvement (e.g. nasopharynx) (Figure 1.11) • To attempt better definition of poorly defined primary lesion on CT, particularly for radiotherapy planning (e.g. oropharynx) MR and CT complementary for paranasal sinuses tumours and mandibular invasion (CT initially preferred)

(Continued)

Table 1.10 (*Continued*) Imaging of maxillofacial malignancy.

Imaging modality	Imaging issues	Comment
PET CT		PET CT may be used: 1. In the setting of symptomatic recurrent disease: • If suspicion of recurrence but biopsy negative • Conventional (CT/MRI) assessment not fully delineated recurrence (due to scar tissue) • Occasionally before undergoing treatment with curative intent to exclude other synchronous primaries/metastases 2. Surveillance imaging: • Persistent primary/nodal disease post-chemoradiotherapy • Surveillance of primary tumour with high risk of recurrence 3. In the setting of an unknown primary tumour ideally prior to panendoscopy and biopsy 4. Rarely for assessment of primary or nodal disease for primary staging
Ultrasound		• There are advantages of ultrasound (relative to MRI/CT) for nodal assessment • Ultrasound uses additional criteria to detect smaller pathological nodes and may also be used to guide fine needle aspiration (FNA) • Utility is guided by local expertise • Particular scenarios in which ultrasound +/– FNA may be required include indeterminate contralateral nodes in the N0 neck using CT/MRI
Chest staging: CXR, CT		CT chest (usually including upper abdomen) usually indicated but depends on local protocols note high incidence of non-specific small nodules which will be detected

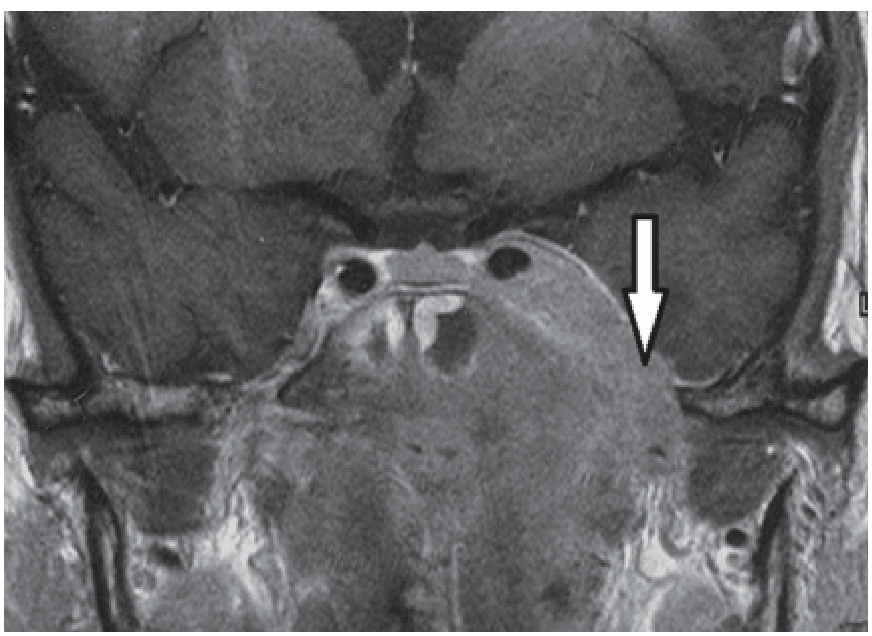


Figure 1.11 Coronal post-gadolinium T1-weighted MR image demonstrates intracranial extension of a nasopharyngeal carcinoma with widening of the foramen ovale (arrow) and infiltration of the cavernous sinus.

Table 1.11 Imaging of maxillofacial skeleton cysts and tumours.

Imaging modality	Imaging issues	Comment
Radiographs	Relationship to teeth Internal density Extent within bone Relationship to mandibular canal Extraosseous extension	Radiographs ideal for showing relationship to and effect on dental structures
CT		CT especially useful to detect cortical breakthrough (Figure 1.12)
MRI		MRI (with gadolinium) has potential to distinguish between cysts and benign tumours (Figure 1.12) Best delineates extraosseous extension (especially within the paranasal sinuses) Used for long-term follow-up of maxillary lesions

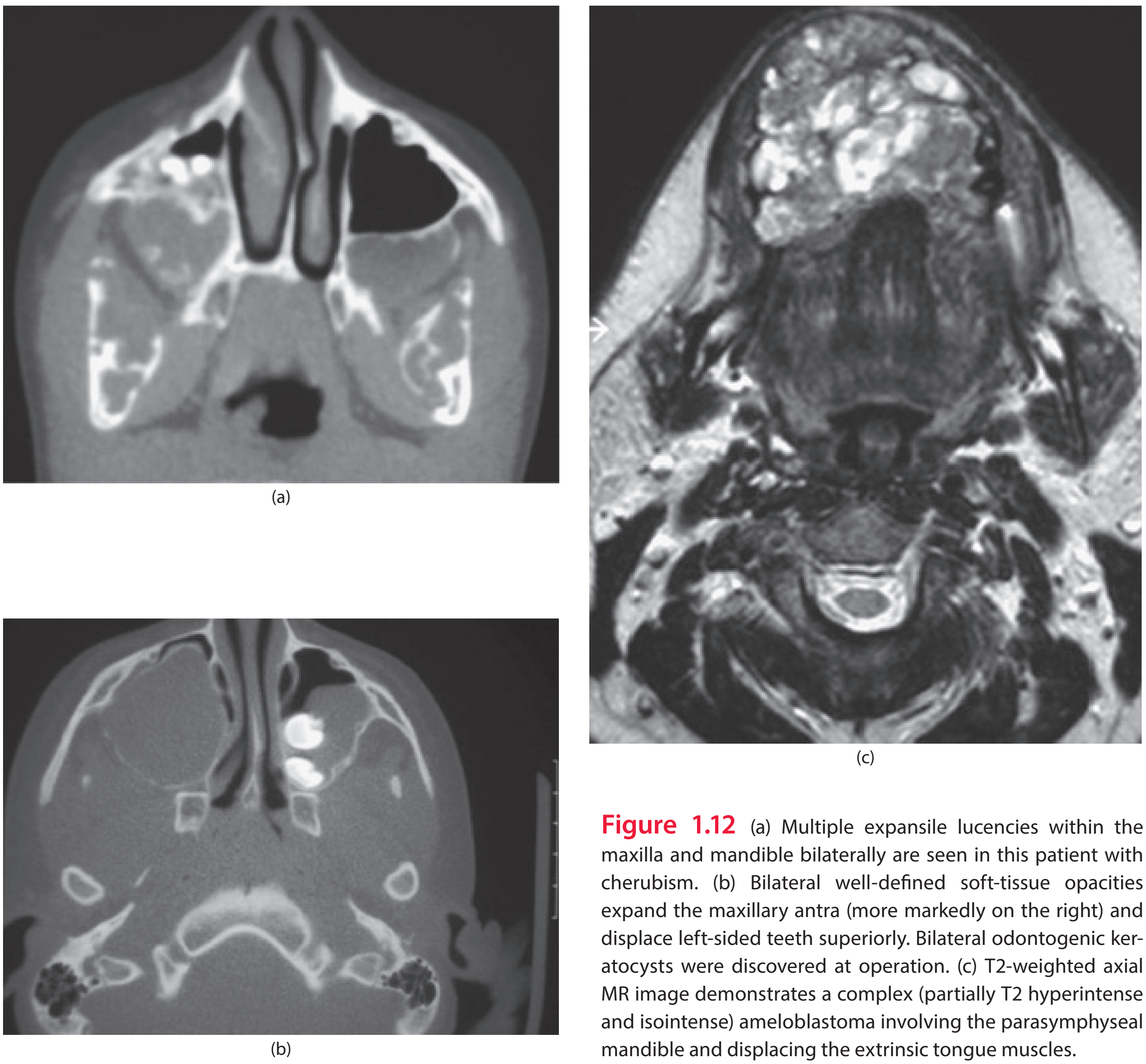


Figure 1.12 (a) Multiple expansile lucencies within the maxilla and mandible bilaterally are seen in this patient with cherubism. (b) Bilateral well-defined soft-tissue opacities expand the maxillary antra (more markedly on the right) and displace left-sided teeth superiorly. Bilateral odontogenic keratocysts were discovered at operation. (c) T2-weighted axial MR image demonstrates a complex (partially T2 hyperintense and isointense) ameloblastoma involving the parasymphyseal mandible and displacing the extrinsic tongue muscles.

Table 1.12 Imaging for dental implantology.

Imaging modality	Imaging issues	Comment
Radiographs (intraoral periapicals and OPG)	Rule out adjacent bony pathology	Radiography required for preliminary assessment
Tomography (linear or complex motion)	Where each implant should be inserted and at what angle Whether there is sufficient bone density and quantity Delineate sensitive anatomy such as the mandibular canal	Tomography or cone beam computed tomography (CBCT) required for direct measurement of prospective implant site Tomography adequate for limited region and where there is no significant anatomical variation
CBCT		CBCT is ideal for implant assessment
CT with post-processing software (e.g. Dentascan or SimPlant)		Conventional–conventional CT has increased radiation dose and cost

Table 1.13 Imaging for orthognathic surgery.

Imaging modality	Imaging issues	Comment
Radiographs (OPG and cephalometry)	Evaluation of skeleton and soft-tissue patterns	Conventional approach is with radiographs
(Low-dose 3D CT)		Low-dose CT is being introduced for complex orthognathic cases 3D data sets and new 3D cephalometric landmarks will overcome the problems of magnification and distortion due to severe facial asymmetry

Table 1.14 Imaging for salivary gland pathology.

Imaging modality	Imaging issues	Comment
Ultrasound	Demonstrating calculi	Ultrasound is the primary imaging modality for most salivary gland disease and guides FNA
Sialography	Diagnosing ductal obstruction (calculi and strictures) and demonstrating appearance of ductal system (e.g. in connective tissue disease) Demonstrating salivary gland parenchymal appearances Distinguishing salivary gland from perisalivary gland masses	Indicated if proximal extraglandular calculus demonstrated by ultrasound (as a precursor to potential radiological intervention for smaller calculi) In the presence of severe obstructive symptoms/sialadenitis (if no calculus demonstrated) in order to detect stricture
Radiographs	Delineating extent (e.g. deep lobe of parotid, perineural extension) of salivary gland tumours	May be used if diagnosis of calculus unclear on ultrasound
MRI/MR sialography		MRI is ideal (and superior to CT) for assessing deep lobe of parotid masses (Figure 1.13), perineural extension of malignant tumours and recurrent tumours MR sialography is used in some centres to evaluate ductal disease
CT		Occasionally helpful if abscess suspected or if multiple calculi

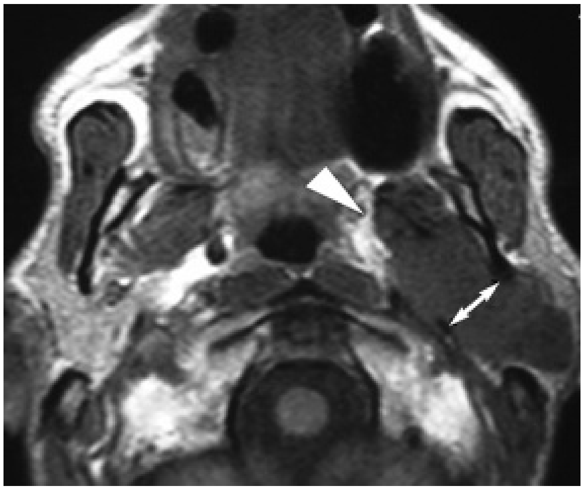
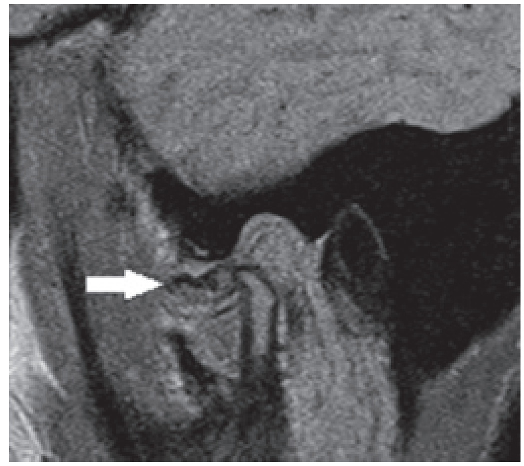
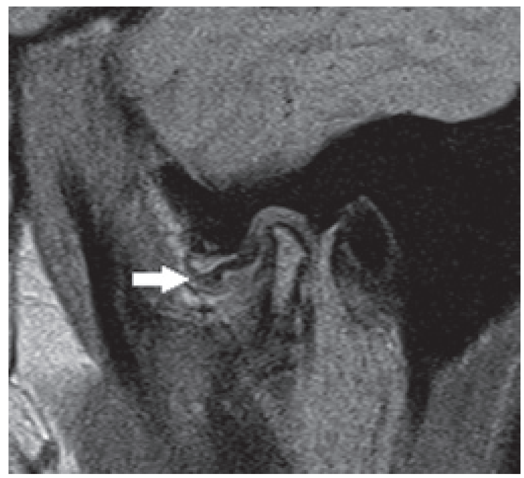


Figure 1.13 T1-weighted MR image shows a parotid mass centred in the deep lobe which displaces the parapharyngeal fat medially (arrow).



(a)



(b)

Figure 1.14 Oblique sagittal proton density-weighted MR images in (a) closed and (b) open mouth positions demonstrate a distorted anteriorly displaced and distorted meniscus (arrows) which does not reduce on mouth opening.

Table 1.15 Imaging of a face or neck mass.

Imaging modality	Imaging issues	Comment
Ultrasound	Cystic or solid lesion Location-common origins ?thyroid ?salivary gland ?nodal	Ultrasound is generally the first line imaging investigation for a palpable mass and this will guide biopsy
CT MRI		CT/MRI are supplementary in order to show deep extension, to identify additional lesions and for staging of malignancy CT guided biopsy may be required for deep face and skull base lesions

Note: ? = possible common origins to consider

Table 1.16 Imaging of temporomandibular joint pathology.

Imaging modality	Imaging issues	Comment
Radiographs	Detection of late bony changes	The majority of temporomandibular joint (TMJ) problems are soft-tissue related The utility of radiography (generally OPG) is limited although it may be used to demonstrate gross bony changes associated with the arthritides
MRI (Arthrography)	Position of the articular disc in the open and closed mouth positions	MRI (Figure 1.14) is non-invasive so has gained greater acceptance than arthrography

2

Ultrasound imaging, including ultrasound-guided biopsy

RACHEL S OEPPEN and RHODRI EVANS

CONTENTS

INTRODUCTION

Ultrasound imaging does not require ionizing radiation and is a relatively inexpensive, non-invasive and readily available technique which is well tolerated by patients. It is particularly useful in examining superficial structures (less than 5 cm deep to the skin surface), where the use of a high-frequency linear probe (7.5–12 MHz) produces high definition images in multiple imaging planes. The spatial resolution achieved by ultrasound surpasses that of either computerized tomography (CT) or magnetic resonance imaging (MRI), and when combined with tissue sampling techniques (percutaneous fine needle aspiration [FNA] for cytology or core biopsy for histopathology), ultrasound is a highly specific diagnostic tool.

Clinicians who have detailed knowledge of the anatomy of the head and neck region may choose to learn how to use ultrasound as an adjunct to clinical examination and as an aid to biopsy techniques. This chapter aims to give an overview of the use of ultrasound in the neck with relevance to clinicians who either want to gain a greater understanding of the technique or who wish to begin to use ultrasound in their practice.

PRINCIPLES OF ULTRASOUND

An ultrasound image represents the reflection and scattering of ultrasound waves caused by variation in acoustic impedance by the various tissues being scanned. A detailed discussion of the physics involved is beyond the scope of this text but essentially the ultrasound probe acts as both transmitter and receiver for sound waves. Images are generated by computerized analysis of the sound waves reflected back to the probe. The higher the frequency of the sound wave generated the greater the resolution obtained, but there is a resultant fall off in penetration with higher frequencies. Typically 8–12 MHz probes are used in assessment of the neck, giving improved resolution for superficial structures but with reduced penetration, i.e. a failure to generate images of deeper structures. This trade-off is not usually a problem in the neck.

Air causes marked scattering of the ultrasound wave; hence, gel is used as the interface between skin and probe to optimize the throughput of the sound wave signal. Gas and bone represent a problem as far as ultrasound is concerned; gas will cause scatter which results in a ‘white out’, while bone and other calcified structures transmit little sound causing acoustic shadowing (black hole). In general, highly reflective tissues appear echogenic (white) on an ultrasound image whereas structures with poor reflectivity (e.g. blood within the internal jugular vein [IJV]) will be hypo-echoic (black) on an ultrasound image. The high reflectivity of some tissues may be desirable (e.g. identification of a core biopsy needle with ultrasound) or undesirable (e.g. a calcified thyroid lamina which prevents assessment of the larynx).

Sadly for the uninitiated, not all hypo-echoic structures are cystic or fluid in composition. Solid structures in the neck that may appear typically hypo-echoic or ‘pseudocystic’ (i.e. black) include lymphoma, salivary pleomorphic adenomata, nerve sheath tumours and parathyroid

adenomata. Conversely, some cysts do not abide by the rules of physics – a 'true' cyst should be hypo-echoic or black on ultrasound but commonly the congenital cysts of the neck (e.g. branchial and thyro-glossal duct cysts) often appear echogenic, i.e. pseudo-solid in appearance.

Colour and power Doppler may be used to assess flow in normal vascular structures (e.g. assessment of carotid arteriopathy and venous thrombosis) and abnormal flow in pathological processes (e.g. hilar vessels in metastatic nodal disease). Colour flow Doppler is standard on most modern machines and can help the beginner to find vascular structures. A power Doppler function is useful for assessing flow patterns, such as the vascularity in lymph nodes (Figures 2.1 and 2.2).

SCANNING POSITION AND BASIC TECHNIQUE

The operator will normally be positioned to the left of the patient, but for biopsies of the left cervical region recommended operator position is to the right of the patient.

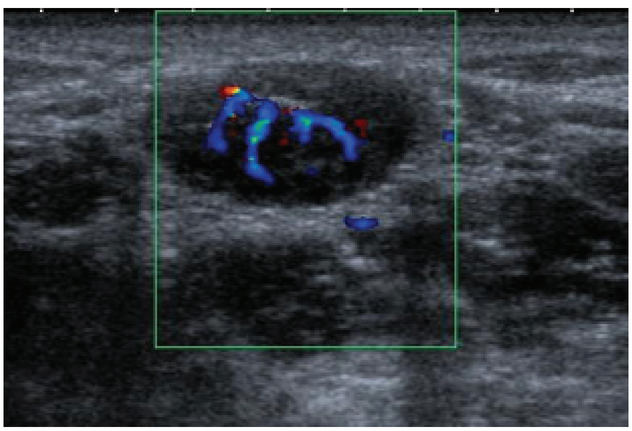


Figure 2.1 Normal hilar vessel, seen on colour flow Doppler in a benign reactive node.

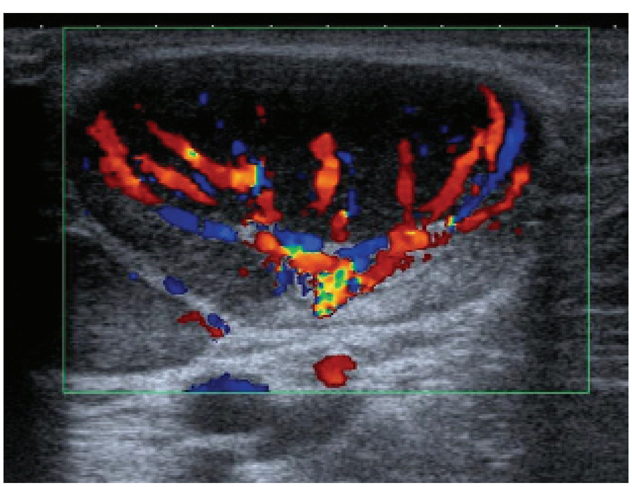


Figure 2.2 Exaggerated blood flow, seen on colour flow Doppler in a lymphoma node.

There must, therefore, be adequate space to allow a range of operator positions in relation to the patient.

The patient should be positioned with the neck extended, using a pillow behind the shoulders. This is sometimes difficult to achieve in patients with cervical spondylosis, in which case the procedure can be performed with the patient sitting or at 45°. Comfort, both of the patient and operator, is essential.

The choice of where to start scanning will depend on the clinical scenario. For example, for a patient with a lipoma of the posterior triangle, a detailed assessment of both sides of the neck is not required, whereas a patient with a squamous cell carcinoma (SCC) primary who is undergoing a staging scan of the neck needs a bilateral assessment of all the major lymph node territories in the neck.

INDICATIONS FOR HEAD AND NECK ULTRASOUND

The following indications will be considered:

- Lymph node assessment
- Salivary glands
- Thyroid gland
- Imaging lumps and bumps
- Ultrasound-guided FNA and percutaneous core biopsy

Lymph nodes

Sonographic criteria for lymph node assessment have been extensively described in the literature. Normal nodes have a well-defined ellipsoid or fusiform shape, with an intermediate to low reflectivity homogeneous cortex and highly reflective central hilus. Overall length is irrelevant, with normal cervical nodes frequently measuring 3 or 4 cm in maximum longitudinal (L) dimension. However, short-axis (S) measurements should not normally exceed 10 mm. An S/L ratio greater than 0.5 implies a round node: the more rounded a node, the more likely it is to contain metastatic disease (Figure 2.3). However, in the submandibular and submental regions, normal nodes tend to be more rounded or reniform, and here shape alone should not be used as a predictor of malignancy. Intra-nodal vessels are visible with colour imaging, and in benign nodes are typically central or hilar in distribution.

Abnormal nodes display reduced reflectivity (i.e. tend to be hypo-echoic or 'black') with a tendency to lose the central echogenic hilus. Short-axis measurements increase, giving a rounder rather than elongated shape. Vascularity may increase and have a disordered pattern. Peripheral or subcapsular vessels, in particular, are a strong sign of malignancy.

Lymphomatous lymph nodes characteristically appear rounded, often retaining a central echogenic hilus and possess a homogenous, hypo-echoic (pseudo-cystic) cortex (Figure 2.4). Colour flow imaging often reveals plethoric

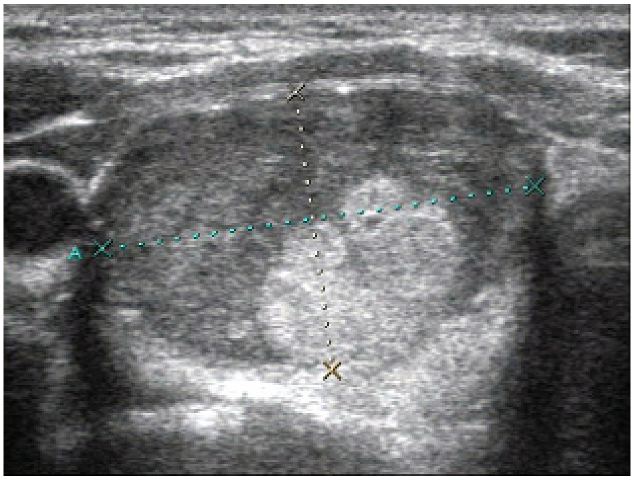


Figure 2.3 Node with greater than normal short/long ratio – a metastatic squamous cell carcinoma node.

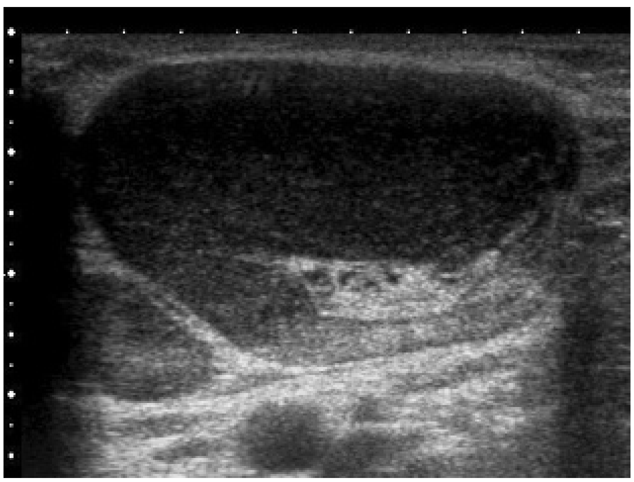


Figure 2.4 Rounded, homogenous, hypo-echoic (pseudo-cystic) cortex of lymphoma.

hilar vascularity (i.e. an exaggerated benign flow pattern) (Figure 2.2). Identification of these characteristics should prompt the operator into carrying out a core biopsy or recommending excision biopsy depending on local preference to allow rapid diagnosis.

Salivary glands

The most common problems encountered include sialolithiasis, inflammatory conditions and tumours.

Submandibular gland

The normal submandibular glands are homogeneous echogenic (bright) structures lying infero-lateral to the mylohyoid muscle in the submandibular space. Intra-glandular ducts are visible as short defined hyper-echoic lines but Wharton's duct is only usually visualized when it is dilated. Lymph nodes in the submandibular space are exclusively extra-glandular.

Parotid gland

The parotid gland lies in the parotid space which is the most lateral space in the nasopharyngeal area, extending from the external auditory canal superiorly to the level of the angle of the mandible inferiorly. The gland is arbitrarily divided into superficial and deep lobes by the facial nerve, but this structure cannot be identified with ultrasound. The retromandibular vein passes superiorly through the parotid and can be used as a landmark for dividing the parotid into superficial and deep lobes, i.e. as a predictor of likely proximity of a mass to and involvement of the facial nerve. The external carotid artery passes through the gland deep to the retromandibular vein. Intra- and extra-glandular nodes are seen in the parotid space. Stenson's duct may be visualized as bright parallel echogenic lines, 3 mm in diameter within the superficial lobe.

Sialolithiasis

Intra-glandular calculi are easier to identify than ductal stones. Frank duct dilatation (Figure 2.5) or sialectasis may be seen, and ultrasound will also demonstrate the complications of calculi; abscess formation and sialocele.

Ultrasound cannot definitively exclude calculi, if there is a strong clinical suggestion of salivary duct obstruction and ultrasound examination is negative, sialography will be required in order to exclude a stone/stricture.

Inflammation

Acute salivary gland inflammation occurs in response to suppurative sialadenitis and viral infection. Inflammation causes gland hypertrophy and hypo-echogenicity, i.e. the salivary glands lose their normal bright echotexture. Ultrasound can be used to exclude abscess formation and may demonstrate hyper-reflective microbubbles of gas in suppurative sialadenitis, which usually affects a single gland, along with reactive nodes. In the case of abscess formation in acute suppurative sialadenitis, ultrasound-guided percutaneous drainage combined with antibiotic therapy may avoid surgical intervention.

Figure 2.5 Dilated submandibular duct (arrowed), typical of ductal stone.

There are two chronic conditions which cause a distinctive 'leopardskin' or 'currant cake' appearance, namely juvenile chronic sialadenitis and Sjogren's syndrome. The distribution of the changes allows a distinction between the two conditions. In Sjogren's disease, the changes are classically bilateral, affecting parotid and submandibular glands, whereas in juvenile chronic sialadenitis there is unilateral change. The classical findings of Sjogren's disease on ultrasound obviate the need for sialography.

The association of Sjogren's disease with lymphoma needs to be recognized and if a hypo-echoic mass is seen within an affected salivary gland, lymphoma must be considered.

Tumours

Approximately 80% of salivary tumours are benign, 80% occurring within the parotid with 80% of these being pleomorphic adenomata. The vast majority of parotid tumours lie within the superficial portion of the gland, allowing easy assessment with ultrasound. However, in the case of large or deep masses, the deep extent of a lesion can be difficult to assess (necessitating CT or MRI). Ultrasound cannot always predict whether salivary gland lesions are benign or malignant (although irregularity, abnormal vascularity and the presence of enlarged or suspicious nodes aids accuracy), and is usually used in conjunction with fine-needle sampling. The smaller the salivary gland the more likely that any tumour detected will be malignant, i.e. a tumour in the sublingual gland has a far higher likelihood of malignancy compared to a mass in the parotid gland.

Pleomorphic adenoma

This accounts for 80% of parotid tumours, arising in the superficial gland in 90% of cases and typically occurs in females over 40 years of age. On ultrasound, pleomorphic adenoma has the appearance of a well-defined, hypo-echoic homogeneous solid mass (pseudo-cystic) with a lobulated border and internal vascularity and may display posterior acoustic enhancement. Smaller adjacent daughter tumours are often identified. Cervical lymphadenopathy is not usually seen.

Warthin's tumour (adenolymphoma)

Warthin's tumour commonly occurs in the elderly male (>50 years) as a lump in the parotid tail, sometimes bilaterally (15%) and is rarely seen in the submandibular gland. It arises from heterotopic salivary gland tissue in parotid lymph nodes. On ultrasound, a Warthin's tumour is usually well-circumscribed and measures less than 3 cm in size. It typically contains heterogeneous cystic and solid areas, or appears pseudo-cystic with through the transmission of sound (posterior acoustic enhancement) (Figure 2.6).

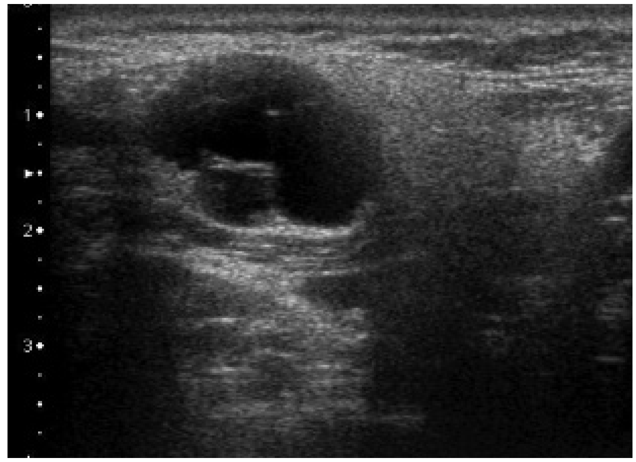


Figure 2.6 Warthin's tumour of the parotid showing cystic change and acoustic enhancement.

Other malignant salivary gland tumours (muco-epidermoid, adenoid cystic and acinic cell carcinomas) occur more frequently in the sublingual and submandibular glands than in the parotid glands. Features suggestive of malignancy include poor definition with heterogeneous echotexture, disorganized colour flow and the presence of associated nodes. Using these criteria, malignancy can be predicted in around 80% of cases using ultrasound alone.

Thyroid

A detailed description of thyroid ultrasound is beyond the scope of this text; however, thyroid disorders, including generalized gland enlargement and focal nodules, are relatively commonly encountered in clinical practice. In the one-stop clinic environment, thyroid nodules are likely to represent the second most common presenting mass, after lymph nodes. The increasing use of ultrasound means that the incidentally detected thyroid nodule is an increasing problem; ultrasound will detect nodules in between 50% and 70% of females over the age of 50. Although thyroid nodules are very common, thyroid cancer is extremely rare. As the thyroid gland is situated in a superficial location in the anterior neck, it is readily imaged with ultrasound, although retrosternal extension may require cross-sectional techniques (CT or MRI) for adequate visualization of caudal extent.

The normal thyroid is a vascular gland with a homogeneous hyper-echoic texture. Adjacent structures, in particular, the common carotid artery and IJV and deep cervical lymph nodes are clearly seen and are routinely examined, and tracheal deviation and retrosternal extension can be appreciated. In some centres, vocal cord mobility prior to surgery is also routinely assessed with ultrasound.

While some thyroid lesions have typical imaging features (e.g. papillary carcinoma), thyroid ultrasound is frequently combined with FNA to improve diagnostic accuracy.

Papillary carcinoma

Papillary carcinoma accounts for 70%–80% of cases of thyroid malignancy. While papillary carcinoma may

be multifocal at presentation, its typical appearance on ultrasound is as a solid hypo-echoic mass. Punctate calcification is a variable finding, but when present is highly specific (Figure 2.7). Invasion of regional lymph nodes is common, and foci of micro-calcification may also be detected in involved nodes.

Thyroid nodules

The typical benign thyroid nodule is usually heterogenous in echotexture, with a hypo-echoic halo or peri-nodular rim. Cystic change is very common and may display the typical 'ring down' or 'comet tail' sign indicating colloid. Calcification is common; either peripheral eggshell or large globular-type calcification. Unfortunately, whether the nodule is solitary or part of a multi-nodular thyroid is not a predictor of malignancy. This myth is often perpetuated but multiple large series have shown that the incidence of malignancy in solitary and multiple nodules is comparable.

A follicular lesion is a predominantly solid, hyper-echoic, homogeneous nodule. Between 80% and 90% of these lesions will turn out to be benign. However, differentiation between an invasive follicular carcinoma and a benign adenoma is not possible without histopathological examination of the entire lesion.

Diffuse thyroid disease

We will consider just one diffuse thyroid disease as this may masquerade as a solitary nodule occasionally, namely Hashimoto's thyroiditis which is the most common form of thyroiditis. This condition causes an enlargement of the gland in the acute phase with diffuse hypo-echogenicity which is typically patchy starting in the anterior portion of the gland. In time the whole of the gland is enlarged, hypo-echoic, contains echogenic striae and is typically hyper-vascular in the acute phase. With time the gland atrophies, loses its hypo-echoic appearance and its vascularity diminishes.

Miscellaneous lumps and bumps

Lipoma

Lipomas are benign encapsulated subcutaneous lesions which are frequently encountered in the neck. Typical sonographic features include hyper-echogenicity, linear internal echoes perpendicular to the ultrasound beam (Figure 2.8), compressibility and a lack of internal vascularity on colour flow or colour Doppler imaging. Intramuscular lipomas can mimic muscle and be difficult to define with ultrasound.

Haemangioma

The head and neck is a relatively uncommon site for haemangiomas. They are frequently seen in the masseter, trapezius and sternomastoid muscles. Haemangiomata may have large cavernous spaces, and possess capillary and/or lymphatic elements. Phleboliths may be demonstrated within the lesion in 70% of cases. In large or intra-muscular haemangiomas, MRI is better at depicting the extent of the lesion.

Branchial cleft cyst

Most branchial cysts arise from the second branchial arch remnants, and present as a mass at the angle of the mandible, often following an infection. The typical location is abutting the posterior aspect of the submandibular gland, lying lateral to the carotid vessels and immediately anterior to the anterior border of the sternomastoid. On ultrasound, these lesions may be cystic, but more commonly the presence of debris, haemorrhage or infection gives rise to a pseudo-solid appearance and the cyst wall thickens in the presence of infection. It may be impossible to distinguish between a second branchial cleft cyst and a necrotic lymph node metastasis due to SCC. Branchial cysts may extend between the carotid artery and lateral pharyngeal wall or have associated sinuses and these features are better demonstrated on MRI or CT than ultrasound.

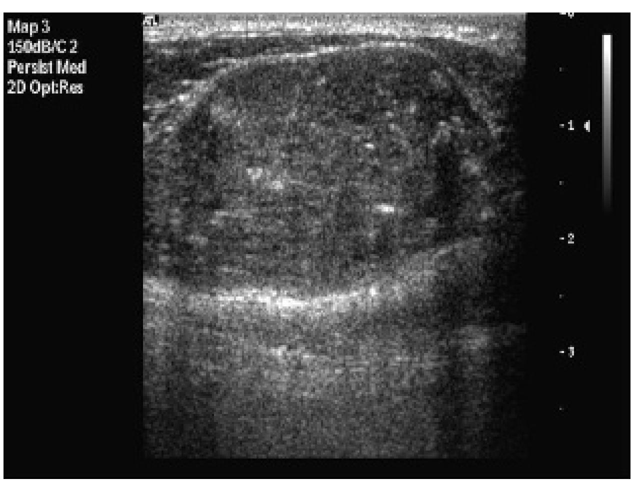


Figure 2.7 Punctate calcification, which when present is typical of papillary carcinoma.

Figure 2.8 Linear internal echoes perpendicular to the ultrasound beam, characteristic of lipoma.

Thyroglossal duct cyst

Thyroglossal duct cysts can arise at any position along the course of the thyroglossal duct remnant but the majority are related to the hyoid bone, with most occurring at the level of or inferior to the hyoid.

On ultrasound, thyroglossal duct cysts may appear cystic, heterogeneous or pseudo-solid due to varying content of debris, haemorrhage or infection. Classically, they are embedded in the strap muscles, often 'splitting' the strap muscles. Malignant degeneration of the epithelial lining occurs rarely and any solid component which appears to contain micro-calcification (i.e. suggestive of papillary carcinoma) should undergo sampling.

Dermoid cyst

Dermoids can be identified by their site, i.e. either midline or peri-orbital. In the peri-orbital region, they are typically (60%) found in the upper outer quadrant of the orbit. These lesions arise from sequestration of the ectoderm from adjacent sutures – most commonly the fronto – zygomatic suture. Dermoid cysts arise from more than one germ cell layer and therefore will contain one or more dermal adnexal structures. Sebaceous glands, hair and fat are commonly found in dermoids but they may also be purely cystic. They may therefore have a heterogenous appearance with the presence of fat manifesting as a fluid/fluid level or often as rounded echogenic masses within the cyst (representing sebaceous rests within the dermoid). The typical location for these midline cysts is in the submental region either superficial or deep to mylohyoid.

Abscess

Infection in the submandibular region frequently arises from dental disease. Ultrasound can differentiate between infection with a fluid component (abscess) and cellulitis, and identify associated lymphadenopathy and venous thrombosis.

Ultrasound-guided FNA and core biopsy

Ultrasound is a very useful adjunct in percutaneous sampling procedures, allowing direct visualization of the needle and structures to be avoided (such as vessels). A metallic needle is a reflective surface and if placed parallel or slightly oblique to the transducer surface, the needle will be imaged as a very reflective or echogenic structure (Figure 2.9). Thus, the needle must be in the plane of the ultrasound beam and as parallel to the probe surface as possible in order to optimally visualize it.

General tips – biopsy techniques

It is essential that the patient and operator are comfortable, when carrying out either FNA or core biopsy in the neck. Keeping the probe, needle, ultrasound monitor and patient in a tight arc, in front of the operator is essential.

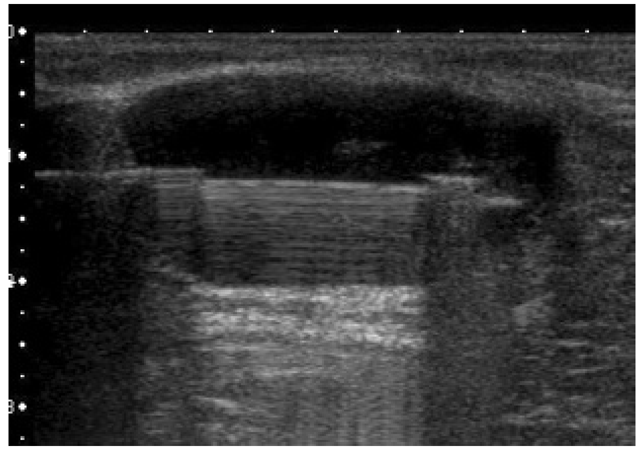


Figure 2.9 US-guided FNA showing reflective surface of the needle.

If biopsy in a lesion in the left neck of a patient, the operator should move to the patient's left, allowing the probe, needle and monitor to lie in a comfortable parallel field of view. If necessary, for example for a lesion in the posterior triangle ask the patient to lie on their side in order to allow easy access for a shallow approach.

Percutaneous biopsy is an outpatient procedure but it is prudent to ask the patient to wait for 5–10 minutes post-biopsy to check for possible haematoma.

Ultrasound guidance should allow a variety of sampling techniques to be performed but if there is a good local cytology service, FNA under ultrasound control may be all that is required. However, where lymphoma is considered as a possible diagnosis, core biopsy undoubtedly has a superior role. Many centres are now able to diagnose and type lymphoma on core biopsy, using flow cytometry techniques, significantly reducing referral to treatment time and avoiding open biopsy.

For many conditions, e.g. SCC lymph node metastases, FNA will be the initial sampling technique. Core biopsy may be reserved as a second-line test when cytology is unable to provide the answer. Some authors advocate the use of core biopsy as a universal first-line investigation, pointing out the fallibility of cytology for certain conditions. However, many others believe that SCC can be seeded during percutaneous wide-bore needle biopsy in the neck. The decision as to which technique to use for sampling neck masses will be influenced by local practice.

A skilled operator should be able to carry out FNA using aspiration and non-aspiration techniques, and if core biopsy can additionally be mastered then there will be few conditions in the head and neck that cannot be sampled under ultrasound control – allowing rapid diagnosis in patients who present with neck masses.

ACKNOWLEDGMENT

We would like to acknowledge Dr. Elisabeth Tilley, Consultant Radiologist, Portsmouth Hospitals NHS Trust.

Top tips

- Echogenic or reflective structures are white (for example bone, needle, calculi).
- Calcification causes complete reflection of ultrasound and an acoustic shadow beyond it.
- Hypo-echoic structures are black (for example blood in the IJV).
- Fluid causes little or no reflectivity.
- Bone, gas and fat are echogenic.
- Congenital cysts are typically echogenic, but branchial cleft cysts, thyroglossal duct cyst, dermoid cysts are pseudo-cystic with some having solid elements.
- Some solid lesions may appear hypo-echoic (have cystic components). These include salivary pleomorphic adenoma, parathyroid adenoma, nerve sheath tumours and lymphoma.
- When assessing nodes, the shape of nodes and blood flow is important.

SUGGESTED READINGS

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3

Surgical and other investigations

GILLIAN L HALL

CONTENTS

In many conditions, the formulation of a definitive treatment plan is based on accurate tissue diagnosis and, hence, biopsy and histopathology are fundamental to patient management. This chapter deals with practical aspects that are of direct concern to surgeons. In addition, practical aspects of other types of investigations such as microbiology will be outlined.

SURGICAL BIOPSY

Surgical biopsy is removal and histopathological examination of a part (incisional biopsy) or the whole of a lesion (excisional biopsy) for diagnosis and treatment. Techniques/tools that may be used include the following:

- Conventional scalpel
- Cutting diathermy
- Punch
- Thick needle (core biopsy)

The choice of incisional versus excisional and technique depends on the indication for biopsy; the clinical diagnosis; the site, size and appearance of the lesion and the ability to close the defect.

Punch biopsy

A punch biopsy is a simple, convenient method of obtaining a disc of mucosa of around 5 mm diameter and this is generally sufficient for histological confirmation of mucosal lesions in conditions such as lichen planus.

Thick needle (core) biopsy

This provides a core of tissue up to 2 mm diameter and 10 mm in length, which is placed in fixative and processed as for a surgical biopsy. It is an alternative to fine needle aspiration cytology (FNAC) and could be used in situations where FNAC has failed to provide a definitive diagnosis. As with any small tissue sample, the core may not be representative of the lesion as a whole or may fail to show specific pathognomonic features.

Core biopsy of a suspected parotid neoplasm in cases with an unhelpful FNAC is generally considered safe especially if narrow-bore needles – less than 0.9 mm – are used. For example, reports show the risk of tumour seeding is extremely low and diagnostic accuracy in distinguishing non-neoplastic lesions, benign and malignant neoplasms is consistently greater than 97%. Conventional incisional biopsy of parotid neoplasms should be avoided because of the risk of seeding in the incision wound (even in benign pleomorphic adenomas), facial nerve damage, facial scar and fistula development.

FNAC is perhaps the first choice technique for analysis of neck and salivary gland lumps. A meta-analysis by Tandon et al. (2008) looking at almost 3500 cases showed sensitivity, specificity, positive predictive value and negative predictive value of 89.6%, 96.5%, 93.1%, 96.2% and 90.3%, respectively. There have been significant advances in liquid-based cytology (LBC) systems, with ability to produce cell blocks from remnants of LBC samples to allow for immunohistochemistry (IHC). Given that the data above will largely derive from the pre-LBC era, it is likely that accuracy and usefulness of this technique have only grown.

Excisional biopsy

Indications

- Simple mucosal and soft tissue lesions – clinically diagnosed as fibroepithelial polyps, inflammatory epulides and mucoceles and so on – where excisional biopsy achieves diagnosis and cure simultaneously
- Where the complete lesion can be removed without risk to important adjacent structures

Technique tips

- Infiltration of local anaesthetic should be into perilesional tissue, taking care to avoid distortion of the lesion.
- A traction suture through the lesion may help in stabilising the surrounding tissue area.
- Care is needed to avoid crushing the tissue with tweezers.
- Any sutures used to control the specimen should be left in place to avoid possible misinterpretation of displaced surface epithelium.
- Following removal, mucosal specimens should be supported by placing the deep aspect on a piece of card in order to prevent distortion during fixation.
- Depending on the specimen, it may be necessary to label specific margins by using marker sutures or labelling a photograph or diagrammatic representation.
- Marker sutures should be tied securely but not pulled tight and should avoid areas of critical interest.
- Colour change following fixation may mask clinically obvious lesions, and, hence, the Pathology Request Form should include details on clinical appearance and size as well as details on site and extent (including depth) of the biopsy.
- Diathermy damages the tissue periphery and may preclude histological assessment of the peripheral 1 mm of tissue, a factor that needs to be considered in biopsy of mucosal malignancies and premalignancies, both proven and potential.

Incisional biopsy

Indications

- To determine the diagnosis before treatment — for larger lesions, lesions that are potentially malignant and lesions of uncertain nature

Technique

- Removal of an ellipse of tissue including both lesional and perilesional tissue

Vesiculobullous/ulcerative lesions

Special care is needed in vesiculobullous/ulcerative lesions.

- Sloughs and necrotic areas should be avoided.
- Superficial biopsies often fragment and are unlikely to include vessels of sufficient thickness/calibre for assessment of possible vasculitis.
- The roof of a flaccid bulla is easily detached and manipulation of tissues before and after biopsy should be minimal.
- Tissue that may require direct immunofluorescent staining (such as demonstration of autoantibodies in pemphigus and pemphigoid) must not be placed in routine fixative solution. Special instructions should be sought from the pathologist before booking the biopsy procedure. Michel's medium is the most commonly used transport medium for such specimens.

Labial gland biopsy

In the investigation of xerostomia, after incising the mucosa, at least six glands should be removed. It is not usually necessary to include the surface mucosa overlying the glands.

Orofacial granulomatosis

In investigation of suspected orofacial granulomatosis (OFG) and related conditions, it is important to remove a good depth of tissue since granulomata are often more numerous within labial muscle rather than the lamina propria and superficial submucosa.

Oral cancer and precancer

Biopsy for histological assessment of leukoplakias, erythroplakias and erythroleukoplakias (speckled leukoplakias) requires careful planning. In many cases, the lesion is too large for excisional biopsy. In general, incisional biopsy should include areas of induration, erosion, erythroplakia and exophytic/papillary growth (Figure 3.1). It is helpful to include adjacent 'normal' mucosa if possible and several geographic biopsies (accompanied by a topographical diagram depicting their site) may be necessary in large lesions especially when non-homogeneous.

Any biopsy for suspected mucosal squamous cell carcinoma must be sufficiently deep to include submucosal muscle – ideally, at least 4 mm in thickness and 10 mm × 6 mm in surface area. Particular care is needed in lesions with an exophytic growth component and the Request Form should give accurate clinical details including the suspected clinical diagnosis. Superficial biopsies can be misleading since the architecture of the rete processes and interface between the epithelium and connective may not be accurately depicted and atypical cytological features may be confined to basal keratinocytes or even focal in distribution.

Assessment of proliferative verrucous leukoplakia, particularly the distinction between verrucous hyperplasia and verrucous carcinoma is notoriously difficult to assess

on incisional biopsy, and the definitive diagnosis may be deferred or amended on assessment of the excision biopsy.

Inclusion of the deep advancing front in the diagnostic biopsy in conventional squamous cell carcinoma allows invasive front histological multifactorial malignancy grading (IFG). The system proposed by Bryne et al. (1998) assesses five features on a four-point scale (Table 3.1) leading to a maximum of 20 points. The first three features relate to characteristics of the tumour keratinocytes while the fourth and fifth relate to the epithelial–connective tissue interface (Figure 3.2). Several independent studies have shown that the total grading score is associated with overall survival (>16 indicating poor survival) and the pattern of tumour invasion (grades 3/4) is predictive of lymph node metastasis.

Figure 3.1 Extensive non-homogeneous leukoplakia of the floor of mouth/ventral tongue requires multiple incisional biopsies – selecting areas of erosion (bottom arrow), exophytic nodules (middle arrow) and thickening/induration (upper arrow). When possible, the biopsy ellipse should include the macroscopic edge of the lesion including a narrow rim of macroscopically normal mucosa.

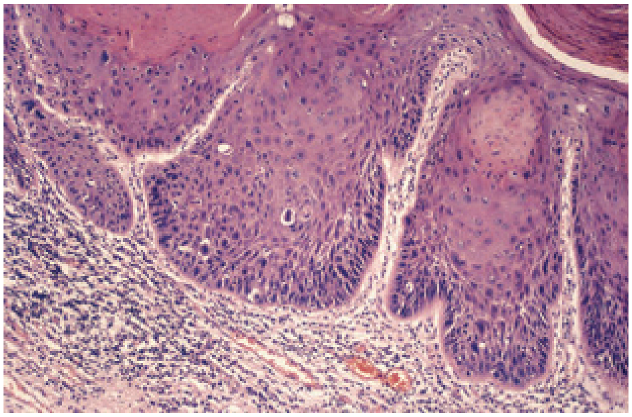
The Risk Model is a newer validated outcome predictor for head and neck squamous cell carcinoma. In brief, it utilizes a scoring system based on worst pattern of invasion, lymphocytic host response and perineural invasion. It is intended for use on excision specimens of low-stage (pT1, pT2) oral cavity squamous cell carcinoma where the whole tumour is available for histological examination. The intention is to assist with treatment planning for patients who might otherwise only receive primary surgery and to guide decisions on elective neck dissection and post-operative radiotherapy. Studies have shown the Risk Model to be significantly predictive of locoregional recurrence and disease-specific survival. At the time of writing, there are suggestions to incorporate this into future WHO Classification texts and if this is the case, the Risk Model scoring will likely become a standard item on pathology reports.

Reproducibility of any scoring system is, of course, subject to inter- and intra-observer variation.

The reliability of incisional biopsy of a clinically suspicious, potentially malignant or dysplastic lesion is questionable. A retrospective study comparing degree of dysplasia in biopsies and 101 definitive excision specimens found concordance in only 49% of lesions rising to 79% when one degree up or down the scale of dysplasia was included. Under-diagnosis of the biopsy was made in 35% of the lesions and over-diagnosis in 17%. Eight percent of lesions that on biopsy (taken on average 10 months previously) showed no, slight or moderate dysplasia harboured carcinomas and 50% of these were clinically homogeneous. Poor reliability of incisional biopsy, possibly due to sampling errors; variation in reading degree of dysplasia; progression (or regression) between biopsy and excision and unimportance of histological appearances suggest that even 'non-dysplastic' lesions should be observed at 3–6 monthly intervals. Unimportance of histology seems, at least, partly responsible since the course of premalignant lesions after

Table 3.1 System assessing five features on a four-point scale.

	Score			
Morphologic feature	**1 Point**	**2 Points**	**3 Points**	**4 Points**
Degree of keratinisation	Heavily keratinised (>50% of cells)	Moderately keratinised (20%–50% of cells)	Minimal keratinisation (5%–20% of cells)	No keratinisation (<5% of cells)
Nuclear pleomorphism	Little (75% mature cells)	Moderate (50%–70% mature cells)	Abundant (25%–50% mature cells)	Extreme (<25% mature cells)
Number of mitoses (per high power field)	0–1	2–3	4–5	>5
Pattern of invasion	Pushing, well-delineated infiltrating borders	Infiltrating, solid cords, bands and/or strands	Small groups or cords of infiltrating cells	Marked and widespread cellular dissociation in small groups and/or in single cells ($n < 15$)
Host lymphocytic response	Marked	Moderate	Slight	None



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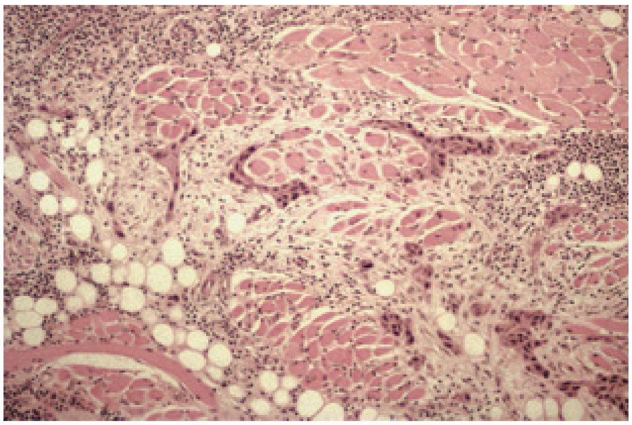


(b)

Figure 3.2 Invasive front histological multifactorial malignancy grading, pattern of invasion and host lymphocytic response. (a) Well-delineated advancing front composed of broad bands of tumour keratinocytes – score 1 point. The host lymphocyte response is moderate – score 2 points. (b) Ill-defined advancing front with tiny tumours islands and individual cells widely dispersed within muscle – score 4 points. The host lymphocytic response is slight – score 3 points.

surgical removal is reportedly independent of their histological diagnosis. Studies looking at variability of grading of oral dysplasia and have suggested a binary system of low-grade and high-grade dysplasia only, eliminating the 'moderate' dysplasia category, and suggest that this leads to improved agreement and predictive value. A binary system may also have merit in helping clinicians to make management decisions. Grading of oral epithelial dysplasia is also subjected to considerable inter-observer variability.

Vital (in vivo) staining

Vital staining with aqueous solution of 1% aqueous tolonium chloride (toluidine blue) is widely advocated as an aid in clinical detection of oral epithelial dysplasia/early carcinoma. The dye binds to nucleic acids and is not a specific test. When applied to clinically suspicious lesions, the sensitivity was 77% and the specificity 67% in one study and 65.5% and 73.3%, respectively, in a more recent study. This more recent study reported positive and negative predictive values of 35.2% and 90.6%, respectively. The technique is said to be less reliable when used indiscriminately on white lesions and ulcers with a high false-positive rate. In addition, the dye is mutagenic leading to concerns about its safety particularly when advocated as a general screening test. Nevertheless, the technique can be of value in deciding the site of biopsy in an extensive lesion, identification of synchronous/metachronous carcinomas, localization of superficial tumour borders during pre-surgical planning and in deciding whether to intervene with surgery or chemoprevention. In addition, toluidine blue staining can identify those high-risk primary oral premalignant lesions with poor outcome even in lesions with low-grade or no dysplasia. The stain is preferentially retained by premalignant lesions with clinical features associated with risk (site, size and appearance); histologically, severe dysplasia and high-risk molecular patterns as assessed by microsatellite analysis. Although there has been a resurgence of interest in toluidine blue in recent years, it should be regarded as an adjunct to clinical diagnosis rather than an accurate test.

Biopsy of soft tissue lesions within bone

Curettage is generally used for the biopsy of tissue within an anatomical or pathological cavity or fistula, and in some conditions, the procedure constitutes treatment. The soft tissues are scraped out with an appropriately shaped curette. All the tissue fragments must be submitted for pathology, including any bone spicules.

The precise diagnosis of odontogenic cysts depends on their relationship to teeth and radiographic details should be submitted on the Request Form. When feasible, teeth should be submitted with the soft tissue *in situ*. In order for thin sections to be cut, specimens containing teeth and bone need to be softened by immersion in acid following their macroscopic assessment in the laboratory. This delays the diagnosis by days or weeks depending on specimen size and composition.

ImmunoHistoChemistry and molecular diagnostics

IHC refers to the process of detecting antigens (e.g. proteins) in cells of a tissue section by exploiting the principle of antibodies binding specifically to antigens in biological tissues. It is a commonly used technique in diagnostic pathology and is routinely employed in the sub-typing of lymphomas and classification of sarcomas. Specific to head and neck pathology, there are IHC stains available that prove squamous differentiation in a poorly differentiated squamous cell carcinoma, where morphologically this diagnosis may not be obvious. Furthermore, stains can be utilized to inform of likely primary site(s) when a patient

presents with metastatic carcinoma of unknown origin, particularly when dealing with an adenocarcinoma.

p16 is an IHC stain which in the setting of oropharyngeal squamous cell carcinoma, and is an excellent surrogate marker for a high-risk human papillomavirus (HPV)-related tumour.

Molecular testing is becoming increasingly important and more widely used in diagnostic pathology. It has been used in the sub-typing of a wide range of tumours for some time, largely sarcomas and lymphomas. Fluorescent *in situ* hybridization (FISH) analysis can be employed to detect single tumour-specific chromosomal translocations which define some of these tumours, Ewing's sarcoma being a good example of this. Other examples of current use are in determining likely response of a tumour to a targeted therapy. For example, in widely metastatic melanoma, DNA extracted from biopsy material can be assessed for a mutation in the *BRAF* gene which if present, predicts for response to tyrosine kinase–inhibiting drugs including vemurafenib. The good news is that FISH and mutational analysis can almost always be performed on formalin-fixed paraffin-embedded tissue and there is rarely a requirement to submit additional fresh tissue at the time of biopsy.

As tumours are increasingly studied at the molecular level, the list of identified tumour-specific and defining translocations grows by the year. Study of salivary gland tumours at the genetic level is one example where in recent times; new information gained from these studies has led to addition of a new entity to the classification, namely mammary analogue secretory carcinoma. Rather than this being a newly occurring tumour, it is most likely that these have previously been designated as acinic cell carcinoma. Information gained from molecular investigation may in future be used to provide prognostic information or guide treatment.

A summary of some of the recently identified salivary gland tumour genetic changes is shown in Table 3.2.

Pathology request form

- Patient identification including surname, forename(s), address, sex, date of birth and unit number. Always check accuracy, legibility and completeness of preprinted stickers.
- Name, address and contact details of requesting consultant/surgeon in charge.
- Details of previous oral/maxillofacial biopsies including laboratory reference numbers.
- The nature of the specimen (skin lesion, mucosal biopsy, bony sequestra, etc.)
- Date and time of biopsy procedure.
- Note any specific risks of infection (including hepatitis, HIV).
- History of current condition (date of onset, duration, location, associated local factors, investigations so far, treatment already received).
- Relevant medical history including current and recent medication.
- Clinical description of the lesion (site, size, colour, surface ulceration, texture, mobility, induration, etc.).
- Clinical diagnosis or differential diagnosis.
- If applicable/relevant, state that the patient has consented for surplus material to be used for research/teaching.
- Type of request: urgent/non-urgent and date of follow-up appointment.
- Name, signature and contact details of surgeon responsible for the biopsy/request form.

Routine histological assessment of fixed tissue samples

High-quality histological sections are dependent on adequate fixation of tissue samples. Depending on specimen size, 6–8 hours of immersion in a formaldehyde-based fixative is the minimum, with 24 hours considered ideal. The volume of fixative solution should be at least 10 times the volume of tissue. Specimens placed in saline and alcohols are often useless for histological assessment and biopsy should be delayed if adequate fixative is unavailable. When special investigations such as electron microscopy are required, the pathologist should advice on the special fixatives that are needed.

Laboratory processing involves dehydration of the fixed specimen by immersion in a series of solvents followed by impregnation with paraffin wax. The wax block supports the tissue which is mounted on a microtome for section cutting. Four microns thick sections are floated onto glass slides and after removal of the wax by solvents, stained.

Table 3.2 Examples of salivary gland tumour translocations recently identified.

Tumour	Translocation detectable by FISH	Comment
Mucoepidermoid carcinoma	t(11,19)	Presence of translocation more commonly seen in low to intermediate grade tumours and associated with more favourable prognosis.
Adenoid cystic carcinoma	t(6,9)	Further research required to identify possible targeted therapies.
Mammary analogue secretory carcinoma	t(12,15)	Most cases previously diagnosed as acinic cell carcinoma. Awaiting longer-term outcome studies to assess whether behaviour is similar, less or more aggressive.

The routine process from placing the specimen in fixative to pathological assessment takes around 24 hours.

Intra-operative assessment of biopsy tissue

The aim is to provide accurate diagnostic information that will determine or alter the course of surgical treatment. The major indications are the following:

- Diagnosis and assessment of the extent of malignant disease/status of surgical resection margins (see Section 6).
- If previous biopsies or FNAC were unsuccessful or equivocal.
- Fresh material is necessary for special procedures including cultures and some molecular studies and it is helpful if the pathologist can check adequacy of tissue sample intra-operatively.

Techniques for intra-operative assessment include the followings:

- Frozen sections
- Crush preparations, smears and touch preparations
- Gross examination

Frozen section technique

This allows histological assessment of a stained slide within 15 minutes of biopsy taking.

- Care is needed in planning the site and size of the specimen — generally, only small tissue pieces (<10 mm) freeze and cut well.
- Specimens should be delivered to the pathologist as quickly as possible, fresh (that is, not placed in fixative solution) but kept moist by a saline-soaked gauze.
- If possible, there should be face-to-face discussion of the correct specimen orientation and identification of specific areas of interest or concern.
- The fresh tissue is quickly frozen (to –70°C), traditionally by immersion in liquid nitrogen but more usually now by placing on a chuck, coating in embedding medium such as OCT, TBS or cryogel and then placing into the cryostat.
- The tissue is thus supported by ice crystals and thin sections are cut on a refrigerated microtome and stained.
- Sampling errors can be reduced by thorough examination of the most critical areas of the specimen. After discussion of the case, the pathologist should ensure that multiple levels (ribbons) are mounted and also, that all remaining frozen tissue is fixed and processed routinely. This allows the routine slides to be checked to confirm or refute the frozen section report.

The appearances in frozen sections differ from those in fixed material – for example, the sections are usually thicker – and freezing artefacts due to poor technique can distort the cellular image further. Hence, a definite diagnosis may not be possible on the frozen sections but the pathological process can be correctly determined in most cases. The overall accuracy of frozen section diagnosis depends on the tissue, pathological process and precision of diagnostic category. The diagnosis of malignant versus benign/reactive can be achieved with 98% accuracy in most tissue types.

Limitations of surgical biopsy and histopathological assessment

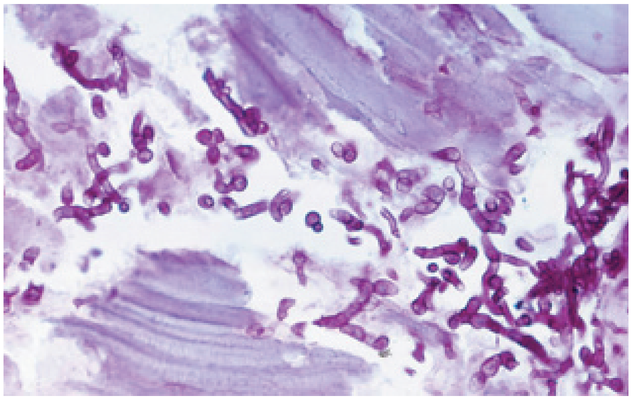
Histological assessment of surgical biopsies remains the mainstay of diagnosis in oral and maxillofacial conditions. Even in conditions such as aphthous ulceration in which biopsy is generally unhelpful, it can exclude other possible causes. Inaccuracies can arise in both clinic and laboratory and include

- Errors in specimen labelling and submission of inaccurate clinical details on the Pathology Request Form.
- Sampling errors at all stages from selection of biopsy site to laboratory trimming of the specimen to inadequate histological sectioning.
- Limitations inherent to the pathological assessment processes.
- Technical errors resulting in suboptimal stained slides. It is the pathologist's responsibility to correct technical problems as they arise.
- Failure of the pathologist to notice critical histological features.
- Pathologist's misinterpretation of histological features.
- Miscommunication such as inadequacies in the written histopathology report.
- Secretarial/clerical errors.

EXFOLIATIVE CYTOLOGY AND BRUSH BIOPSY

Exfoliative cytology, examination of cells scraped from the surface of a lesion, is a quick, simple method of sampling surface cells without need for local anaesthetic. It is widely used for detecting candidal hyphae, virally damaged keratinocytes and acantholytic keratinocytes of pemphigus (Figure 3.3). The area is scraped with a flat plastic instrument or dry tongue spatula and exfoliated cells are transferred to clean labelled microscope slides. Air-dried slides are used for Giemsa staining and alcohol-fixed slides for Papanicolaou staining. Special staining techniques including IHC can be applied to the cellular smears to improve diagnostic specificity. The surface scrape provides no information on deeper tissues, and, hence, is unreliable for diagnosing cancer by simple cytology.

The brush biopsy, vigorous abrasion with a stiff bristle brush, collects cells from the surface and subsurface layers



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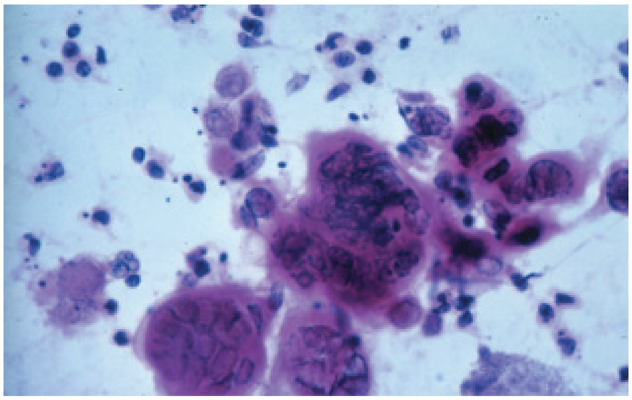

(b)

Figure 3.3 Exfoliative cytology. (a) Candidal hyphae are readily detected in a smear stained with periodic acid Schiff (PAS). (b) Virally damaged cells are evident in the fluid and cells of vesicles and ulcers in herpetic stomatitis.

of a lesion and is a simple, convenient way of obtaining DNA samples. To ensure sample is sufficiently deep, the brush should be rotated in one spot until bleeding occurs. The cells are transferred from brush to a microscope slide. For optimum accuracy, cellular assessment involves a range of techniques such as scanning by an image analyser, measurement of nuclear DNA content and molecular analyses such as loss of heterozygosity and microsatellite instability. Overall, the literature suggests the brush biopsy may provide a reliable diagnostic sample once the assessment techniques have been more fully evaluated and one potential future use could be in monitoring molecular changes in pre- or potentially malignant oral lesions.

MICROBIOLOGY

A wide range of techniques can be used to aid diagnosis:

- Exfoliate cytology and smears (see above) for rapid confirmation of acute pseudomembraneous candidosis (thrush), acute ulcerative gingivitis and herpetic stomatitis.
- Culture and sensitivity of pus organisms. The sample should be taken before giving an antibiotic.
- Swab and enzyme-linked immunosorbent assay (ELISA) for virus detection.
- Molecular biological tests such as polymerase chain reaction (PCR) and fluorescent FISH for rapid identification of bacteria and viruses. PCR identification of mycobacterium, for example, takes around 48 hours and is more sensitive and specific at differentiating different types of mycobacteria that traditional culture and sensitivity tests.

Fresh samples are necessary, or at least preferable, for most microbiological and molecular tests and the microbiologist or pathologist should provide guidance on the exact nature and preservation of the sample.

HAEMATOLOGY, CLINICAL CHEMISTRY AND SEROLOGY

Blood investigations are essential for the diagnosis of blood dyscrasias and defects of haemostasis, and helpful in investigations of other oral conditions such as chronic candidosis, sore tongue and aphthous ulceration. Blood must be placed in the appropriate tube since some anticoagulants are incompatible with certain tests and the request form should include sufficient clinical detail to permit the haematologist or clinical chemist to check that appropriate tests have been ordered and to interpret the results. In difficult cases, advice should be sought prior to taking the blood sample.

Top tips

- Plan the biopsy type and the tools/techniques used, the precise site(s) with due consideration of the purpose of the biopsy, the clinical features of the lesion and the clinical differential diagnosis.
- Small, superficial and crushed tissue samples may be non-diagnostic. Consider both the surface area and depth of the biopsy specimen. Tissue shrinks (on average 30%) during fixation and processing for routine histological assessment.
- For routine histological assessment, the biopsy specimen should be placed immediately in a formaldehyde-based fixative (at least 10× the volume of tissue).
- Consult the pathologist before taking the biopsy when special investigations are required. Fresh tissue samples are necessary for immunofluorescent staining, microbiological testing and some molecular techniques.
- Always check the accuracy and completeness of the information on the pathology request form and the specimen pot label.

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4

3D modelling for head and neck surgery

STEPHANIE J DREW and SALVATORE L RUGGIERO

CONTENTS

Three-dimensional (3D) stereolithic modelling has evolved to be the gold standard for planning complicated reconstruction of ablative and traumatic defects of the head and neck (Figure 4.1). The advent of new computer software has enabled the surgeon and biomedical engineers to create and use virtual surgical planning. From the virtual plans, surgical guides from the data collected and analysed are produced and used in the operating room. The power of this innovative software has enabled the surgeons to precisely evaluate the complex 3D anatomy of the defect or deformity and then plan for the alignment of the grafts for the newly constructed functional and aesthetic skeleton of the jaws, orbits or cranium.

Before computer planning is utilized, the doctor must first determine what type of graft the patient will require to fill the defect. This includes both hard and soft tissue transplants. Vascularized grafts, free autogenous grafts, allogeneic bone cribs filled with marrow or titanium-milled prosthesis are all choices available to the surgeon. There are multiple anatomic challenges of a 3D nature that occur when harvesting a tubular bone such as the fibula, or a flat bone such as the ilium. These grafts require reshaping to conform to a specific anatomic location and become a functional mandibular or maxillary skeletal unit. When using vascularized grafts, the position and orientation of the graft will also be dictated by the position of the pedicle relative to the location of recipient vessels that are being anastomosed.

Once the location of the donor graft is chosen, the bone must then be reshaped and inset within the defect. The alignment must support the soft tissue, maintain bone contact and be aligned in a way that will allow the dental unit to be ultimately constructed for optimum function and aesthetics.

The computer planning technology permits 3D assessments of the defect. The construction requires information from several sources. First, the clinical examination, including dental casts, if appropriate, is used to determine the occlusal relationship. Currently,

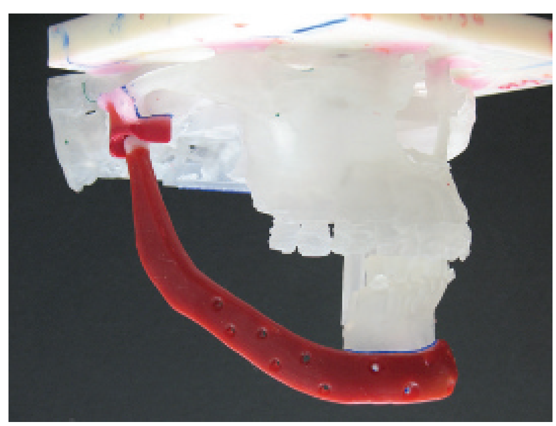


Figure 4.1 Example of the use of 3D stereolithic models in mandibular reconstruction.

scanning of the occlusal surfaces of the teeth by computed tomography (CT) or cone beam scan along with the use of dental models is the most widely used technique. The scans of the dental models are then superimposed over the CT scan dentition and a composite model is then created. However, the current occlusal scanning orthodontic software available allows the incorporation of direct surface scanning of the patient's dentition. This may become available to integrate into our reconstructive treatment planning protocol. This product may obviate the need for dental casts. It may be difficult to take dental impressions at times on patients that have undergone resection surgery because of decreased range of motion. Next, the Digital Imaging and Communications in Medicine (DICOM) data from CT scanning or cone beam scanning are utilized to obtain the necessary image data to allow for precise planning. Specific protocols have been established for the different machines available (Figure 4.2). The scans delineate the defect location of the recipient bone and also of the donor site bone if possible.

Virtual planning begins with determining the margins of the resection if ablative surgery is going to be part of the reconstruction. Otherwise, the post-ablative defect is defined with the radiographic analysis of the scans. If necessary, anatomic stereolithic models can be constructed from the data to aid in treatment planning and hardware positioning. Next, the donor bone is evaluated and the length and shape of the bone to fill in the defect are identified. A virtual donor bone is then brought into alignment with the defect (Figure 4.3). If osteotomies are required to create the correct alignment of the donor graft, then this should be accomplished at this time (Figure 4.4). When the position of the donor graft is satisfactory, the engineers will then create virtual 'mitre box' cutting jigs/guides for precise translation of the virtual surgical plan to the donor bone for execution of the virtual plan in the operating room (Figure 4.5).

The power of computer planning allows for precise positioning of these osteotomies. The orientation and position of the osteotomy sites may be easily repositioned at this stage in order to obtain the ideal orientation of the graft relative to the recipient site. One other powerful feature of computer planning is that alternative sites such as the 'ilium vs. fibula' can be evaluated on the screen (Figure 4.6).

Timing is also an important factor when it comes to virtual planning. The computer information must be 'cleaned' of any data that will interfere with the planning. This process takes several hours of the engineer's time at the modelling company once they receive the DICOM data sets. The medical grade CT scanners data sets have less to 'clean' than the cone beam machines. Thus, one must realize that the planning sessions cannot happen instantly at this time. It will take several days before a planning session appointment can be made.

An appointment must be made by the surgeon to have a virtual planning session with the engineers. These sessions typically take about 30 minutes. Once the plan has been accepted, then the modelling company will produce the needed cutting jigs, plate/screw hole drill guides, 3D stereolithic model if needed and occlusal splints. The shipping location must be predetermined and enough time needs to be allocated so that the material will arrive prior to the surgical date. The materials are usually received within 14 days following the treatment planning session. If a custom prosthesis or custom plate is required, then the processing time could take 2 months or more.

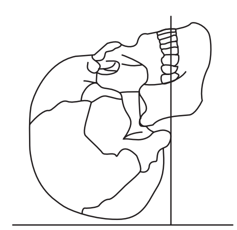
In addition to planning the position of the grafted bone, the possibility of dental implant placement into these grafts may also be assessed with the virtual planning software. If

Recommended protocol for medical CT scanners

Scan Spacing:	Less than 1.25 mm (equal to slice thickness)
Slice Thickness:	Less than 1.25 mm (equal to scan spacing)
Field of View:	20.0 – 25.0 cm
Algorithm: (examples)	GE: Standard (not bone or detail) Siemens: H30s Toshiba: FC20 Philips: B
Gantry Tilt:	0°
Archive Media:	CD or DVD
File Type:	DICOM (uncompressed)
Series:	Original/Primary/Axial

Patient positioning

Occlusal plane should be parallel to the gantry.



Recommended protocol for CBCT scanners

Scanner	Scan Time	Voxel Size	Field of View
Classic i-CAT*	40 sec	0.4 mm	16 cm (d) × 13 cm (h) (Preferred) Extended FOV: 16 cm (d) × 22 cm (h)
Next Generation i-CAT*	26.9 sec	0.4 mm	16 cm (d) × 13 cm (h) (Preferred) Extended FOV: 23 cm (d) × 17 cm (h)
Gendex* CB-500	40 sec	0.4 mm	14 cm (d) × 8 cm (h) (Preferred 14 cm (d) × 8 cm (h)
Iluma™ Cone Beam CT	40 sec	0.3 mm	[Portrait] 14 cm (w) × 18 cm (h) (Preferred) [Portrait] Extended FOV: 16.4 cm (w) × 18 cm (h)
Other CBCT Scanners	Longest Available	0.3 – 0.5 mm	Largest Available

Figure 4.2 Protocols for CT and Cone Beam scanning.

Figure 4.3 An example of the donor bone scan being superimposed on the area to be reconstructed.

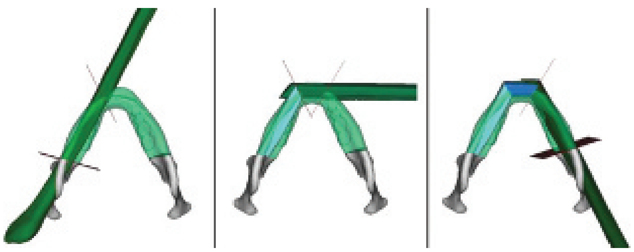


Figure 4.4 The images can be manipulated to demonstrate the position of osteotomies.

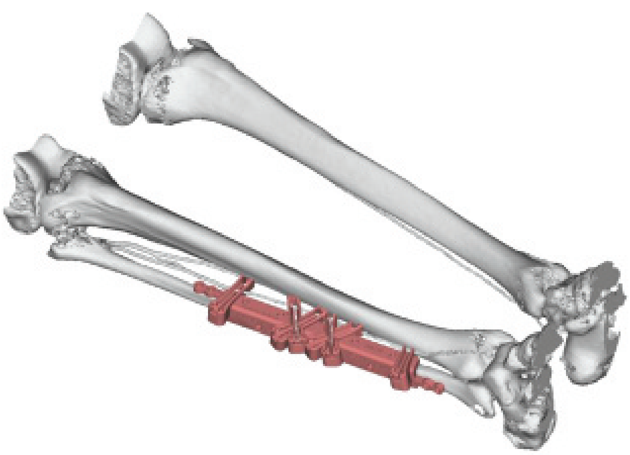


Figure 4.5 Cutting jigs can then be planned on the 3D images and then surgical jigs are constructed in the laboratory.

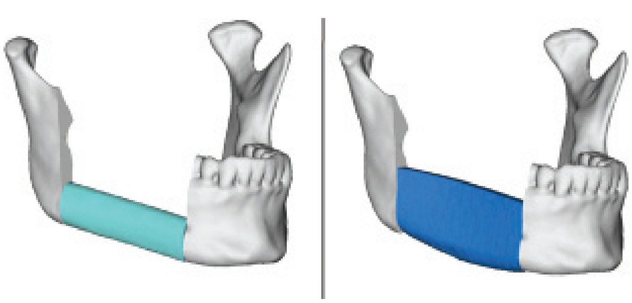


Figure 4.6 3D planning can also be used to compare different donor sites such as fibular (left image) and iliac bone (right image).

the alignment is precise and the bone volume is adequate, then placement of implant analogues into the virtual plan at the time of the planning session can be accomplished easily. From this dental rehabilitative plan, the engineers can also create drilling guides for the surgeon to use to place implants either at the time of reconstructive surgery or in a delayed fashion if dictated by the circumstances (Figures 4.6 and 4.11).

THE MANDIBLE

The work horse for mandibular reconstruction of segmental defects is the fibula free flap. However, the iliac crest graft may also be considered. Both types of grafts offer sufficient bone stock to accommodate dental implant placement either at the time of the graft placement or after graft healing. The limitations of these grafting techniques are discussed at length elsewhere. The customization of these bone graft units for mandibular defects is most accurately accomplished with the use of computer planning. To prepare for this technique, the native mandible and the native fibula should be scanned. The DICOM data are then uploaded into the treatment planning software. The ablative portion of the procedure can be planned as well as the orientation of the fibula segment within the defect. When designing the fibula osteotomies, it is important not to compromise the vascularity of the donor bone by creating segments that are too small. If that is done, the perforator vessels may be violated and the segment may lose its viability. Generally, the segments should be no less than 2 cm in length.

SPECIFIC CHALLENGES OF RECONSTRUCTING DIFFERENT MANDIBULAR REGIONS

Ramus of the mandible

This region of the mandible is anatomically challenged by the relationship of the graft to the remaining mandibular segment after resection. Typically, if the ramus is resected the coronoid process is also removed to prevent the condylar segment from rotating up. This leaves the recipient site with a very thin piece of bone to graft, diminishing the surface area of contact and the ability to get stability and good bone healing. If the amount of condylar segment remaining will be very small, consideration should be given to replacing the entire unit, both ramus and condyle.

Temporomandibular joint replacement

The temporomandibular joint (TMJ) is able to be replaced by multiple types of osseous vascularized and non-vascularized grafts as well as custom-made titanium prostheses. The fibula is the work horse for a very long span with vascularized tissues. However, the use of custom-made joint prostheses may also be considered. This would

decrease the length of the grafts needed. It is also available if a patient is not a candidate for a vascularized graft. There have even been total joint replacements that include the ramus and part of the body of the mandible for this reason.

Body of the mandible

The body of the mandible articulates with the ramus posteriorly and the parasymphyseal and symphyseal areas anteriorly. This portion of the mandible requires planning to include the possibility of replacing the missing dentition that will be removed along with the resection. Once the choice of graft is determined, the 3D planning should account for the need to place the vertical position of these grafts to allow for support of implant dentistry or prosthetic reconstruction. Although the graft may be able to receive dental implants, the vertical position of the graft will dictate the size/height of the superstructure that is created to support the prosthesis. The longer the distance/height, the more likely the prosthesis will come under stresses that may possibly lead to failure of the hardware.

Midline of the mandible

Considerations for the midline region are similar to the body of the mandible in terms of the dentition; however, this area is not as long as the other regions of the mandible and care must be taken while planning not to create a small segment that will lose its vascularity. The osteotomies created must support this important biologic principal for good healing. This area of the mandible when reconstructed with the fibula will be challenged by the height of bone available to fill the defect. Solutions here for the use of the fibula would be to consider placing the graft about 10–15 mm below the occlusal plane, using the 'double barrel' technique of folding the fibula in half or vertical distraction once the bone is healed. All of these techniques should provide enough bone for dental implant rehabilitation.

CHOICE OF GRAFT FOR MANDIBULAR RECONSTRUCTION

Which to choose? Fibula or ilium? It is all about location, location, location! Tissue, tissue, tissue! There is no bone that specifically matches the anatomy of the mandible, or the maxilla for that matter. The 3D modelling, both virtual and stereolithic, can be created to determine the need for either bone or muscle or skin, the ability to see the surgery virtually (practice!) and create templates and guides to use in the operating room to increase precision for a functional reconstruction.

Use of the Jewer classification is helpful to reflect the complex nature of the reconstructive defect and guide the decision-making in planning surgery. The mandible is divided into the anterior mandible, the lateral mandible and the ramus/condyle.

Central defects include both canines are designated 'C'.

Lateral segments that exclude the condyles are designated 'L'.

When the condyle is resected with the lateral mandible, it is designated 'H' for hemi-mandibular.

There can be eight possible combinations of these letters. That would be L, C, H, LC, HC, LCL, HCL and HH.

The type 'L' defects can be reconstructed with a straight bone graft. The type 'C' defects typically require multiple osteotomies (Figure 4.7).

Soft tissue modifications to the classification system are as follows:

- 't': tongue defect
- 'm': mucosal defect
- 's': external skin defect

The complexity of the reconstruction becomes more difficult as the number of modifiers is added to the defect identification. For instance, if a patient has a defect classified as 'HLmt', it would require replacement of a great deal of bone and soft tissue as well as the TMJ.

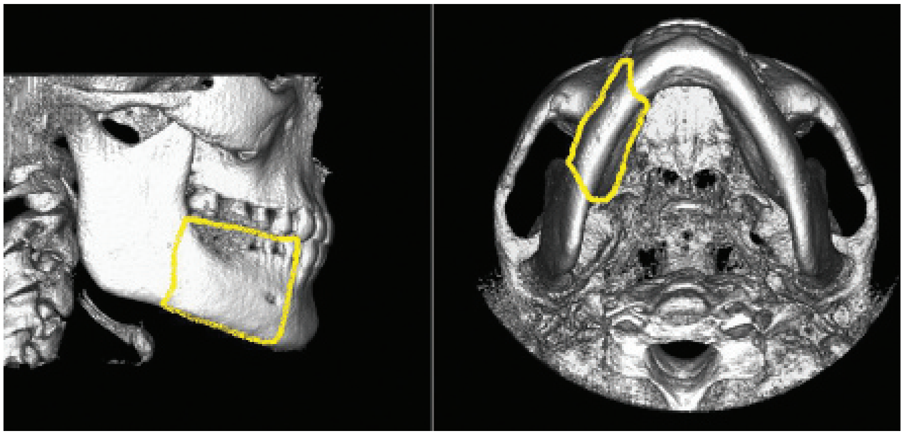
Fibula grafts provide up to 25 cm of length of bone. The soft tissue pedicle can be up to 15 cm. The vascularity of this graft is amenable to multiple osteotomies and is good to use for H, L and C defects. There is enough bone stock for placement of dental implants.

The ilium is large and can be harvested from 6 to 16 cm. The bone is also curved which may be good for the type L and C defects. The length of the pedicle is only 5–7 cm. A single osteotomy can be created to reconstruct the C type of defects with care to keep the periosteum and iliacus muscle intact to maintain the blood supply. The bone is thick enough to receive dental implants. The best defects for the ilium are H, L, C or combination defects.

The scapular osteocutaneous free flap is good for a large quantity of soft tissue replacement. The bone can be up to 14 cm with a pedicle of 6–9 cm. Multiple osteotomies are difficult for this graft, however, it can be split into two bone segments. This flap also comes with a large amount of skin and soft tissue. It can also receive dental implants. The radial forearm osteocutaneous free flap provides a large amount of soft tissue. But, bone position of the flap is only a short segment of monocortical bone up to 14 cm. This cannot have osteotomies or dental implants. Thus, this should be reserved for short segments of L defects that require large amounts of soft tissue replacement.

HARDWARE ISSUES

3D planning can also help with the alignment of the reconstruction bone plates that will be needed to stabilize these bone grafts.[1] They can be made two different ways. First, a stereolithic model can be fabricated and mailed to the surgeon with the resection defect set. The surgeon can then prebend the plate to the defect. The plate is then sterilized to



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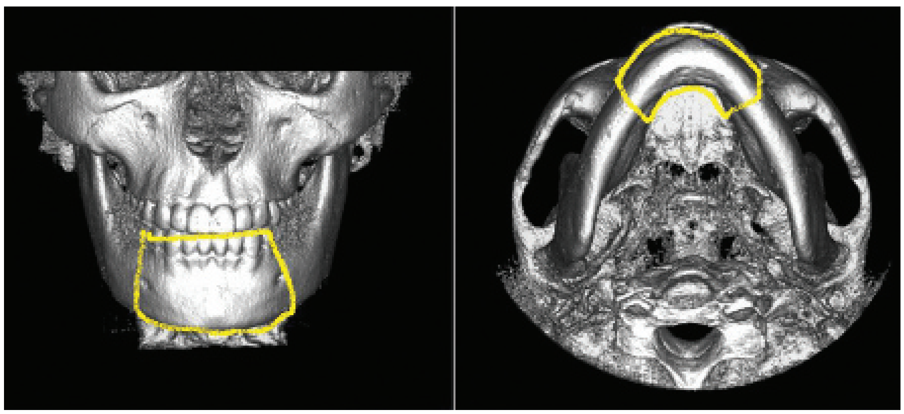

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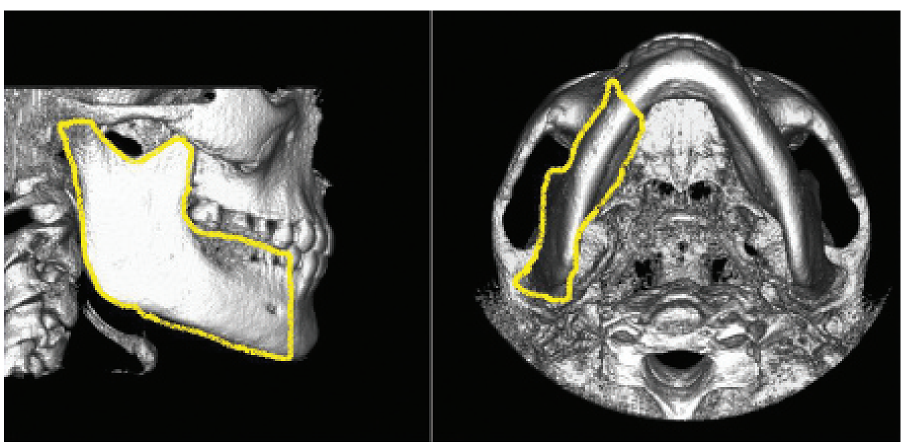


(c)

Figure 4.7 Examples of mandibular resections using the Jewer classification.

use in the operating room. Although the plate is bent to fit the anatomically correct patient specific model, the surgeon cannot precisely free hand this alignment in the operating room. The surgical cutting jigs are used to resect the mandible; the bone plate is then aligned based on its relationship with the model. Marks on the plate can be made to help with the alignment as well as distance from the inferior border of the stereolithic model to transfer to the patient's mandible in the operating room. This may increase accuracy and needs to be validated with appropriate studies. The stereolithic model can also be sterilized to use at this time as well. The accuracy of this technique, however, is not as great as when a custom plate is bent or milled by the plating company and used with drill hole guides to place the place more precisely.

THE MAXILLA

The anatomic challenges of stabilizing a graft to reconstruct the maxilla not only require a bone that will support the alveolus but also the nose and possibly the orbital region.

Brown et al.,[2] in 2000, described and classified the type of defects created by ablative surgery to help identify the possible function and aesthetic demands on the reconstruction. The classification is divided into vertical and horizontal components (Figure 4.8).

Vertical component

- Class 1: Maxillectomy without an oro-antral fistula
- Class 2: Low maxillectomy (not including orbital floor or contents)

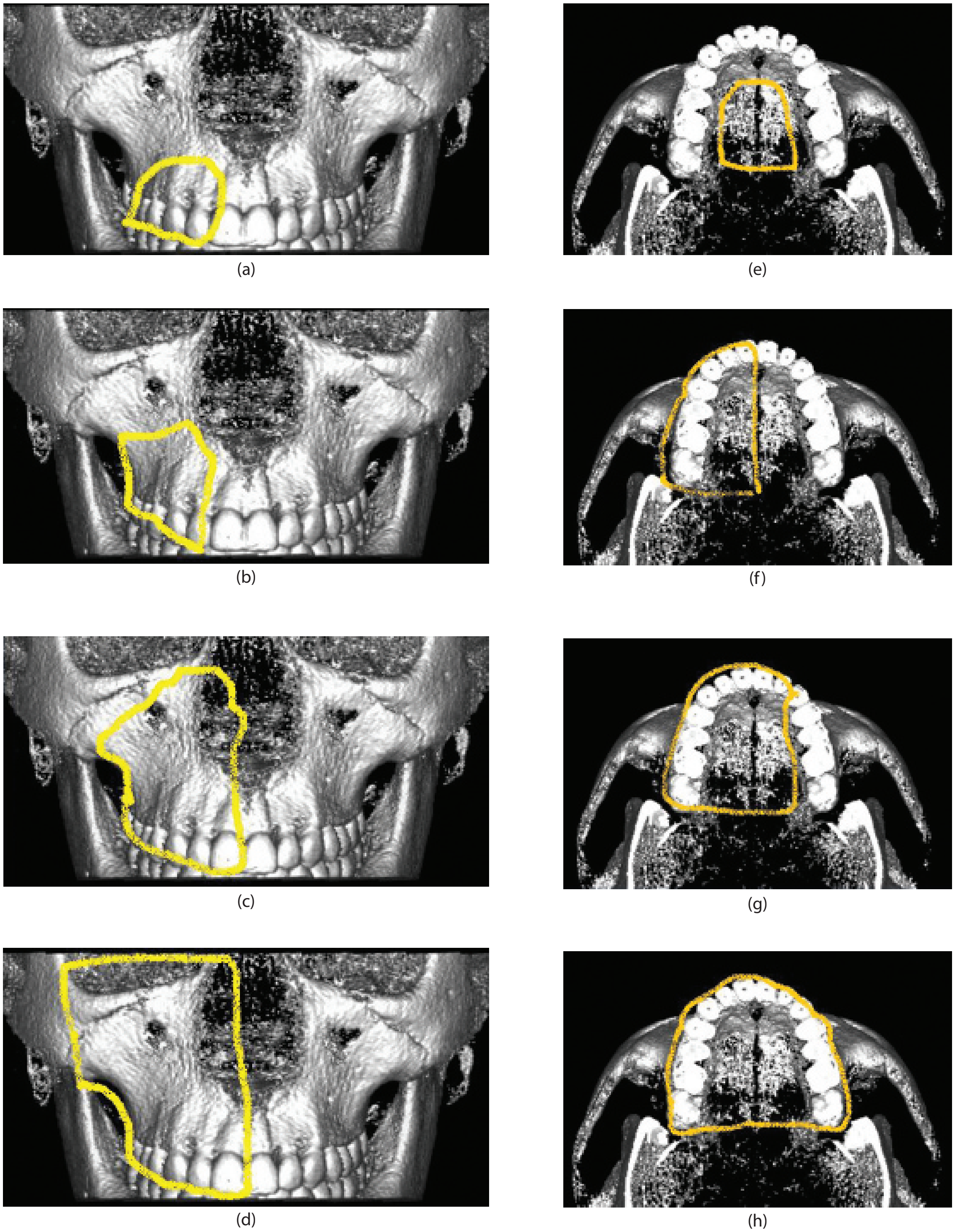


Figure 4.8 Classification of maxillary defects according to the Brown et al. classification (a) Class I, (b) Class 2, (c) Class 3, (d) Class 4, (e) Class 1, (f) 'a', (g) 'b' (h) 'c'.

- Class 3: High maxillectomy (involving orbital contents)
- Class 4: Radical maxillectomy (includes orbital exoneration)
- Classes 2–4: They are qualified by adding the letter a, b or c

Horizontal or palatal component

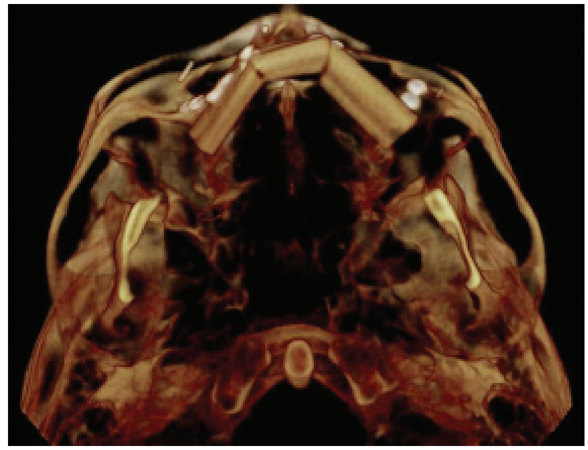
- Unilateral alveolar maxillectomy
- Bilateral alveolar maxillectomy
- Total alveolar maxillary resection

Based on these defect descriptions, the choice of graft material can be determined. The need for bone reconstruction typically falls in the Classes 2–4 regions. The small Class 2 defect may have a number of bone reconstruction choices including the fibula, iliac crest, scapula or radial free flap. However, with increased size the choices go down. Once the defect is located in the Class 3 region, the iliac crest or scapula can be used and in the Class 4 defect the iliac crest and a large soft tissue free flap from the rectus, latissimus dorsi or anterolateral thigh flap are necessary to fill this large defect and support the nose.

DENTAL IMPLANTS

The dentoalveolar unit is the most difficult to reconstruct with bone grafting for segmental defects of the jaws. If the alveolus and soft tissues can be replaced, a truly functional reconstruction can be achieved. The prosthetic demands for replacing missing dentition need to be kept in mind with the final reconstruction. There must be enough room for components of the implant abutments and superstructures for fabrication of the dentition (Figure 4.9a and b). The minimum height of bone required to place standard implants predictably is 10 mm. However, the width of the graft also needs to be taken into consideration. Since implants range from 3 to 6 mm in width a cuff of bone no less than 1 mm is necessary for integration. The advent of thinner and shorter implants may give us the ability to place them in smaller pieces of bones; however, they need to withstand the functional demands of chewing once the prosthesis is in place. Taking into consideration, that many of these patient may be irradiated, one must not increase the risks of osteoradionecrosis due to hardware failure and possible infection due to poorly planned prosthesis design.

With this concept in mind and knowing that the particular anatomy of the fibula, ilium, scapula or radius may lack 'wiggle room', virtual planning and fabrication of drilling guides will help the surgeon place these fixtures whether primarily or delayed in a more precise fashion.



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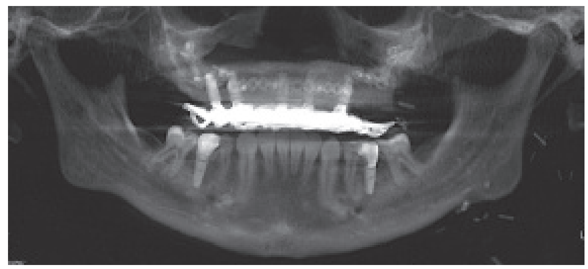


(b)

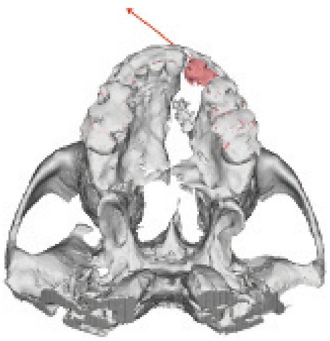
Figure 4.9 There must be sufficient bone to accommodate the implants.

DISTRACTION OSTEOGENESIS AS AN OPTION FOR RECONSTRUCTION AND VIRTUAL PLANNING

Distraction osteogenesis in reconstructive surgery has two purposes. First, the distraction hardware can be used to increase the height of the bone grafts after they have healed. This technique is used to create the dentoalveolar bone needed for implant placement at the correct vertical position for rehabilitation. This technique will require a single vector to distract. Virtual or stereolithic model planning here will allow for cutting jigs and drill guides to be made as well as alignment of the distractors for the correct vector.

The second area where distraction can be used is in recreating the alveolus and soft tissues with L and C defects of the mandible as well as maxilla (Figure 4.10a through c). This technique is able to 'grow' the whole length of the mandible if needed and there is enough bone stock available. This, however, may not be very practical as only 1 mm per day of bone can be grown. However, if a small unit of bone needs to be made such as from the canine to the second molar region, the alveolar bone can be predictably recreated to the areas where the dental implants need to

(a)



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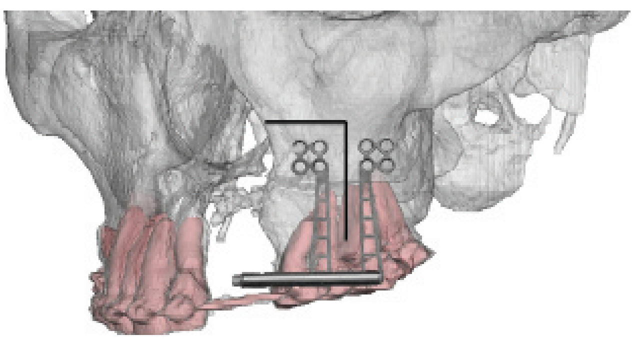


(c)

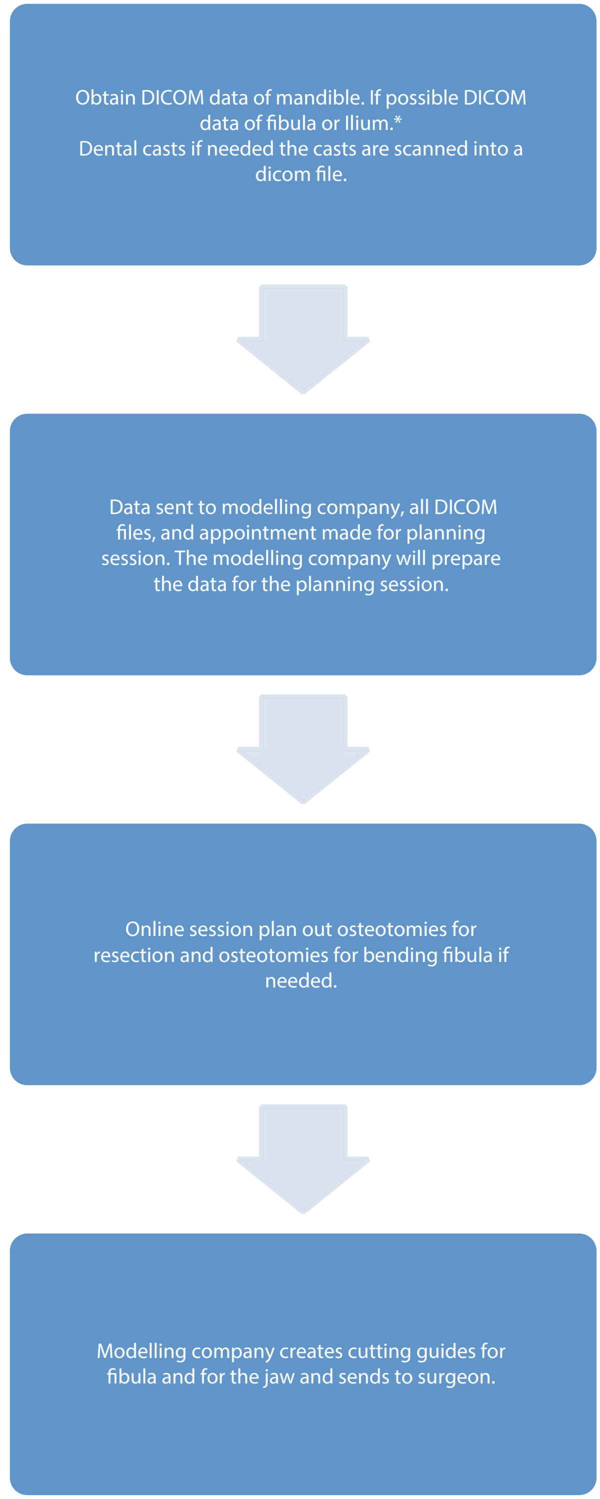
Figure 4.10 Distraction osteogenesis can be utilized to close maxillary alveolar defects.

be placed then the remainder of the defect can be grafted with non-vascularized bone.

Once again virtual planning will allow the surgeon to visualize the vector or path of the transport segment, plan for the alignment of the plate needed to stabilize the proximal and distal segments of the reconstruction, and align the distractor itself with drill guides and osteotomy jigs.

CONCLUSION

Virtual planning is quickly becoming the standard of care for planning complicated surgical procedures across many specialties.[3] Computer-assisted surgery supports



*The modelling company has stock osseous virtual models of the fibula, ilium and scapula if these patient-specific scans cannot be done. They have both male- and female-sized bones. The virtual bones can be used and a 'best fit' scenario created then translated with the cutting jig/mitre box created off these stock bones into the operating room.

Figure 4.11 Work flow for use of the fibula and ilium, scapula or radial forearm flaps.

the surgeon while making difficult decisions with diagnosis, operational planning and even intra-operative navigation. Surgery requiring movement of skeletal components in three dimensions for many different types of surgical problems requires sophisticated planning tools to precisely navigate through the surgery planning and the operation itself. The combination of this virtual planning technology, along with the fabrication of stereolithic models, splints and custom hardware, as well as the translation of this data into computer navigation systems will increase safety and accuracy. Virtual reality is the new frontier of surgery.

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SECTION II

ORAL SURGERY AND IMPLANTOLOGY

5

Tooth extraction

CATHERINE BRYANT

CONTENTS

INTRODUCTION

The extraction or removal of a tooth from the alveolus is a very commonly performed procedure, despite the increasing trend for the preservation and retention of teeth throughout life. Dental extractions can usually be performed in a controlled, atraumatic manner following careful evaluation of the patient and the tooth to be removed. All patients benefit from the increased comfort and reduced recovery time afforded by limiting the extent of surgical trauma. The avoidance or minimization of bone removal during dental extractions and the use of luxators and periotomes facilitates this to a greater degree than is possible with conventional techniques.

There are many indications for tooth extraction including caries, periodontal disease, pulpal necrosis, pericoronitis and traumatic injury. In addition, extractions may be indicated prior to orthodontic or prosthodontic treatment and before radiotherapy or treatment with bisphosphonates and other antiresorptive medications which may complicate subsequent extractions.

An intra-alveolar or 'forceps' extraction is one in which a tooth is removed from the alveolus without the surgical creation of a pathway for its delivery. A transalveolar or 'surgical' extraction is one which requires a mucoperiosteal flap to be raised, allowing visualization of the tooth and invariably bone removal to facilitate its removal. This technique may be used electively where factors precluding forceps extraction are appreciated from the outset or when a tooth proves resistant to, or fractures during attempts to deliver it with forceps.

PRE-OPERATIVE EVALUATION AND PREPARATION FOR A DENTAL EXTRACTION

Most of the difficulties, unpleasantness and complications associated with dental extractions can be avoided with proper pre-operative assessment and planning. Assessment of a patient's general health, their level of anxiety about the procedure, the condition of the tooth for extraction and its radiographic appearance all contribute to this evaluation. Patients requiring special measures to be taken before or after the extraction can therefore be identified so that the associated risks may be minimized and the surgical outcome is optimal. All patients should therefore undergo well-planned procedures with appropriate pain and anxiety control.

Given a cooperative patient, the vast majority of dental extractions can be completed successfully under local anaesthetic. For those patients who are anxious

or undergoing prolonged or unpleasant procedures, intravenous sedation with midazolam offers a safe and reliable adjunct, producing around 40 minutes of anxiolysis, sedation and amnesia. Since local anaesthetic techniques provide a similar window of pulpal anaesthesia, it is widely accepted that procedures predicted to take longer than this should be done in stages or under general anaesthesia. General anaesthesia is therefore rarely indicated for dental extractions. Its use should be restricted for patients unable to cooperate with treatment in any other way or where there is a degree of urgency to complete treatment but the presence of acute infection precludes the achievement of effective local anaesthesia.

The preparation of a patient for a dental extraction must include an explanation of the proposed treatment and appropriate warnings about the associated sequelae. Administration of a pre-operative analgesic, to utilize its pre-emptive effect and reduce pain experience post-operatively, and mouth rinsing with chlorhexidine should also be considered.

The operator usually stands to extract teeth, although technique and positioning can be modified to allow patients to be treated supine. Patients undergoing extraction of maxillary teeth should be positioned with their mouth level with the operator's elbow and the dental chair reclined so that the upper arch lies at an angle of 60° to the floor (Figure 5.1).

For the extraction of mandibular teeth, the chair should be lower and reclined slightly less so that the lower arch is parallel to the floor (Figure 5.2).

During routine extractions, the surgeon stands in front of the patient on the same side as his own dominant hand, except for mandibular extractions in the quadrant on the same side as his dominant hand. For these the surgeon should stand behind the patient. When a surgical extraction is performed, the operator usually stands adjacent to the quadrant being treated to allow the best possible view and access.

INSTRUMENTS AND TECHNIQUES USED TO EXTRACT TEETH

An extraction may be successfully completed with the use of extraction forceps alone. Dental elevators are, however, often used to assist with the luxation of a tooth and the dilation of its socket prior to extraction with forceps, in addition to being essential to the removal of teeth and roots during surgical procedures. A range of new instruments, designed to remove teeth atraumatically prior to implant placement have recently been introduced. These 'extraction systems' work by screwing a post into a retained root and pulling it out, as a cork from a bottle, by turning a screw connected to the root.

Figure 5.1 Positioning of a patient for the extraction of a maxillary tooth.

Figure 5.2 Positioning of a patient for the extraction of a mandibular tooth.

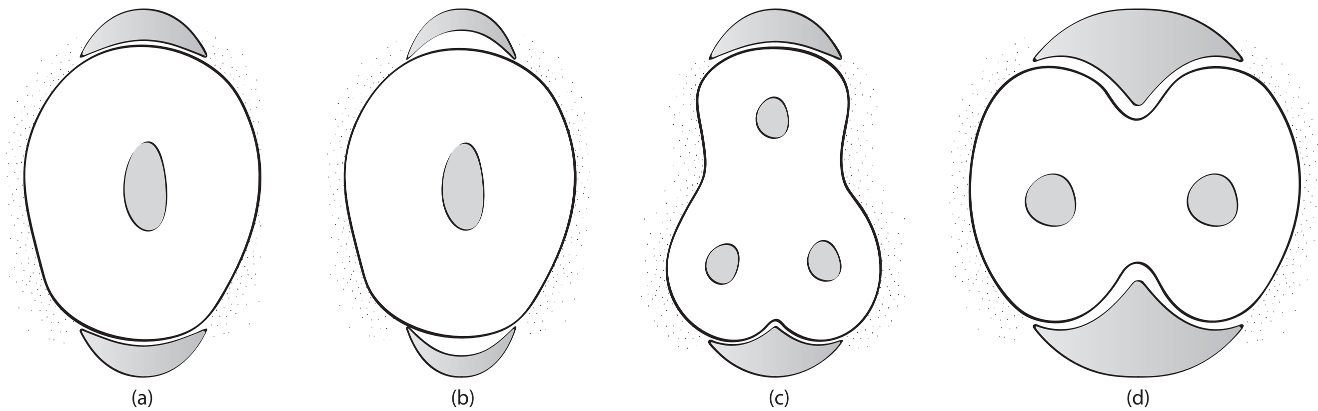


Figure 5.3 (a) Even distribution of force to tooth with closely adapted forceps. (b) Blades which are too narrow distribute force unevenly. Molar forceps have beaks to engage the radicular maxillary (c) or mandibular (d) bifurcations.

Extraction forceps

A wide variety of forceps is available with operator preference and the anatomy of the tooth being removed determining those selected for use. The pattern of mandibular extraction forceps in general use differs between the United Kingdom and the United States. In the United States, the blades of such forceps run in line with the handles, curving downwards to engage the buccal and lingual surfaces of a tooth. When in use, the handles enter the mouth from the front, are in line with the dental arch and are usually held with the palm of the hand facing upwards, the 'underhand technique'. In contrast, the mandibular forceps used in the United Kingdom have blades which run 'fore and aft' perpendicular to the handles, which cross the dental arch at right angles during an extraction. The principles of use are common to both. The operator must find the forceps comfortable to grip and the blades should fit closely around the tooth with the beaks engaging the radicular bifurcations (Figure 5.3).

When using forceps to extract a tooth, two movements are involved. The first severs the gingival and periodontal ligament attachment to the tooth. The blades should be positioned beneath the gingival margin on the buccal and lingual aspects of the tooth and then driven with increasing force in an apical direction. Thus, they slide along the length of the root surface to their final position rather than gripping it from the outset. The placement of the forceps in the most possible apical position possible ensures that the mechanical efficiency of subsequent movements to extract the tooth is maximal and the risk of root fracture is minimized. The wedge shape of the blades also dilates the socket (Figure 5.4).

The second movement of forceps extraction removes the tooth from the alveolus. Whilst the apical position achieved in the first movement is maintained, the tooth should then be gripped firmly by the blades of the forceps and the tooth luxated in its bony socket. This allows the socket to dilate and the tooth to be lifted out. The movements involved should be slow and deliberate, allowing time for the alveolus to expand; their direction will be determined by the anatomy and position of the tooth being removed. Resistance to such forces should prompt consideration of a surgical approach.

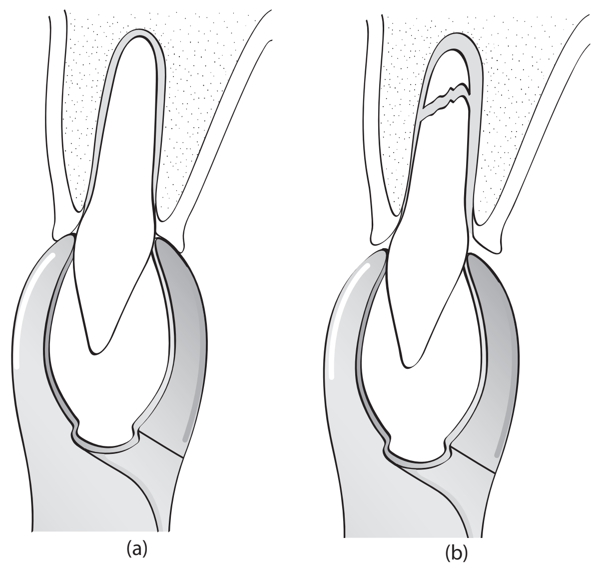


Figure 5.4 (a) and (b) Failure to seat forceps apically results in a more coronal centre of rotation during the movements of the extraction. This increases the degree of movement of the root apex and predisposes to its fracture.

Forceps technique

Maxillary teeth

- Incisors and canines: Figure 5.5
- Premolars: Figure 5.6
- Molars: Figure 5.7

Mandibular teeth

- Incisors, canines and premolars: Figure 5.8
- Molars: Figures 5.9 and 5.10

Dental elevators and their use

A wide variety of elevators is available. Although apparently very different in design, their common feature is their curved blades. The blades transmit forces, generated by rotating the handles around their long axis, to the surface of the tooth or root. This produces luxation and movement of the tooth away from the point of application, where the elevator contacts the tooth.

Forces may be applied perpendicular to the tooth with an elevator in the interdental space or along its long axis buccally. Since considerable force is applied to the tooth, the elevator must be prevented from slipping. Whilst it is being used, the operator's index finger should therefore be extended along the length of the blade to act as a finger rest on adjacent hard tissues (Figure 5.11).

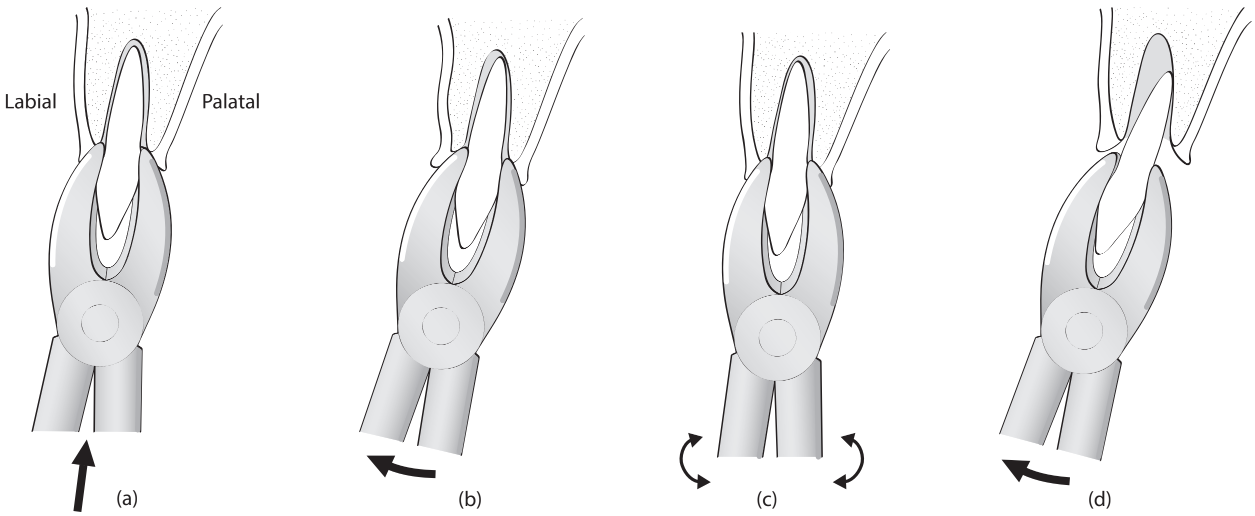


Figure 5.5 (a) Upper straight or universal forceps are seated as apically as possible. (b) Slow, steady labial movement followed by release then palatal movement is repeated with gradually increasing force. (c) Rotational movements may be introduced to completely sever the periodontal ligament fibres. (d) The tooth is delivered labially.

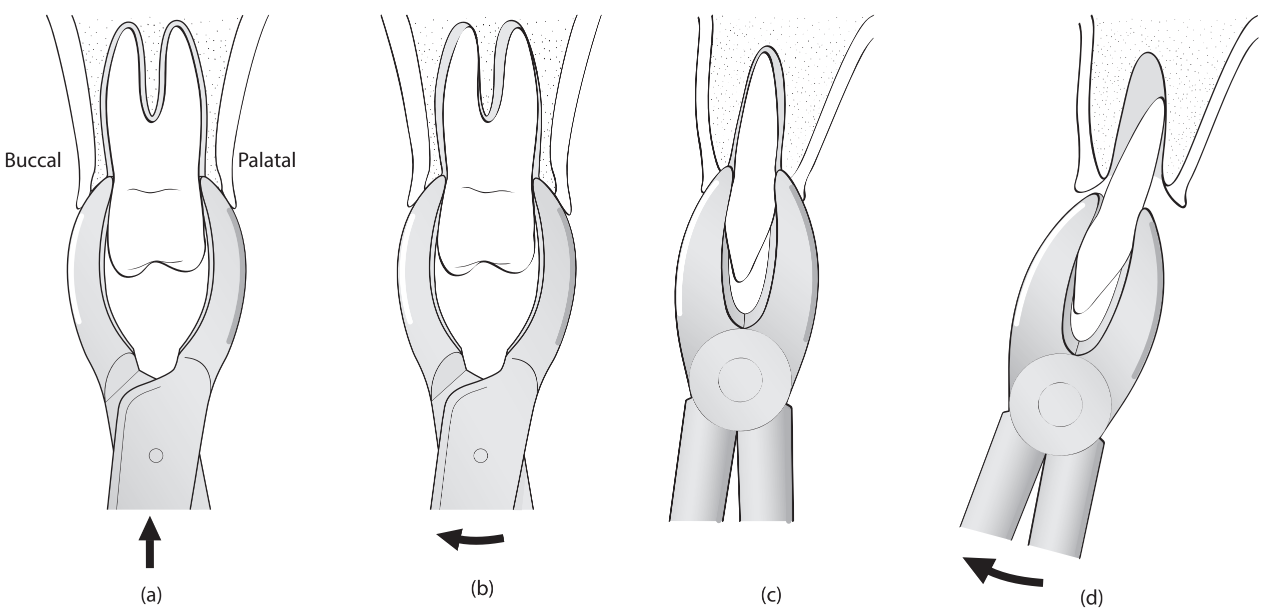


Figure 5.6 Prior to the application of forceps, the first premolar should be luxated to prevent fracture as this tooth is often two rooted. (a) Upper premolar or universal forceps engage the tooth firmly and apically. (b) Buccal pressure is applied to the tooth. (c) Gentle palatal movements are introduced. (d) The tooth is delivered in a buccal direction, with additional tractional force to remove the tooth from its socket.

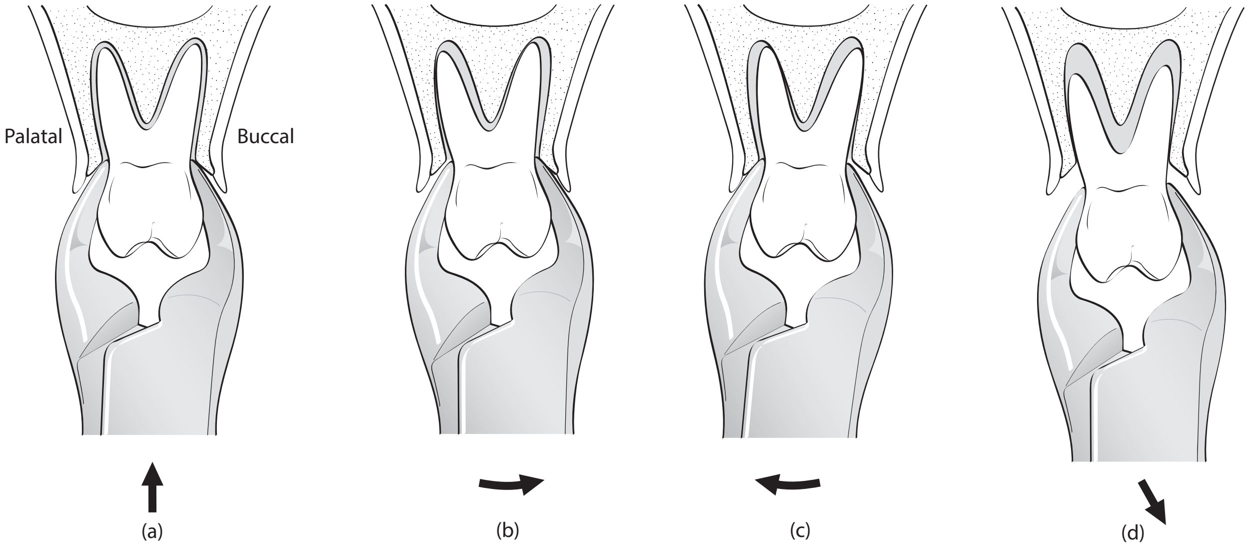


Figure 5.7 (a) Upper molar or anatomical forceps should be seated with their beaks engaging the buccal bifurcation. (b) The predominant movement is buccal and significant force may be required. (c) Palatal forces can be applied, although the palatal cortical plate is thick and unyielding. (d) Firm steady buccal pressure allows the socket to expand and the tooth is delivered in this direction.

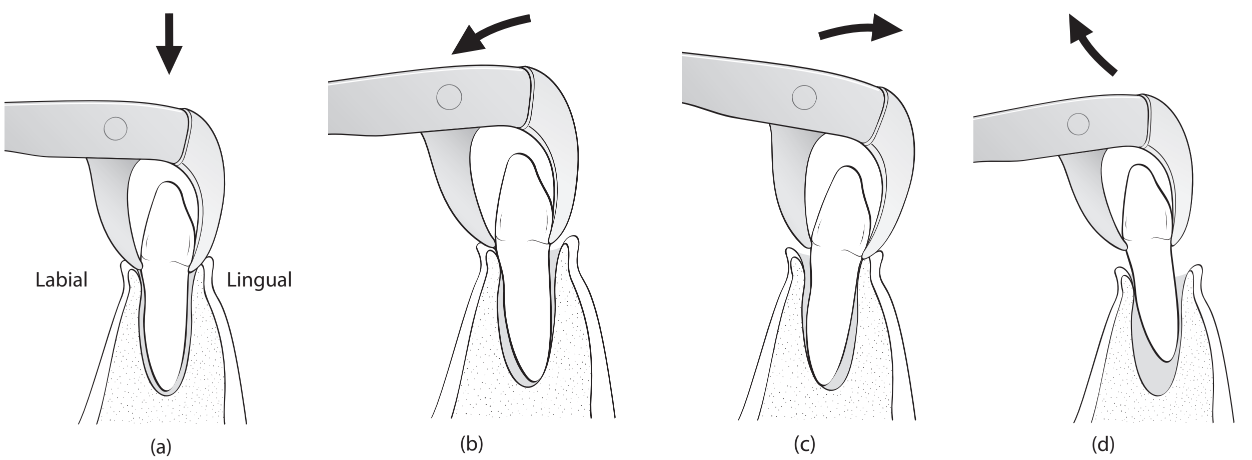


Figure 5.8 (a) These teeth with similar, single conical root morphology are removed with lower premolar or universal forceps which are positioned as far down the root surface as possible. (b) Force is applied labially and then lingually (c). Rotational movements are introduced until the tooth is finally delivered in a buccal–occlusal direction (d).

The curved blade of the elevator is placed on the root surface, thus lying between the tooth and the alveolar bone which acts as a fulcrum around which the elevator is turned.

Rotation of an elevator used in this way will produce a force which luxates the tooth and tends to displace it out of its socket (Figure 5.12a).

An equal force will also be applied to the fulcrum, so it is important to ensure that this is alveolar bone capable of resisting such a force and not an adjacent tooth which may as a result become inadvertently loosened or displaced (Figure 5.12b).

Elevators must be used with caution when luxating teeth to avoid generating excessive and potentially damaging forces. Should a tooth resist attempts to luxate it, another solution should be sought.

Luxators

Luxators are sharp, fine, slightly flexible single-bladed instruments, not unlike Coupland's elevators in appearance. They are used to incise the soft-tissue attachment of a tooth whilst sliding down the periodontal space to an

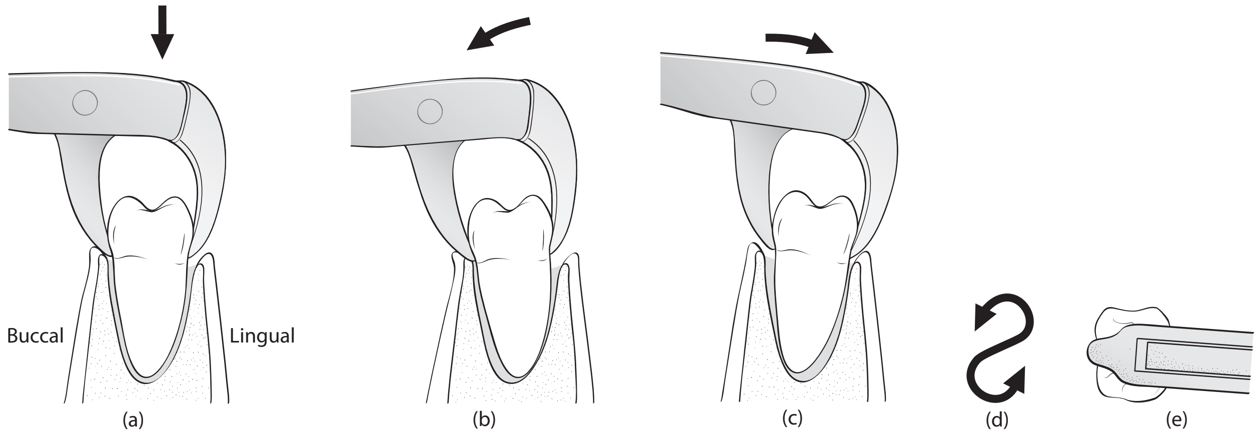


Figure 5.9 (a) Lower molar forceps are positioned with beaks engaging the bifurcation buccally and lingually. (b) Buccal and lingual (c) excursions are made, with increasing force as the tooth begins to become mobile. (d) A figure of eight movement independently dilates the mesial and distal sockets. (e) Tooth is delivered in a bucco-occlusal direction.

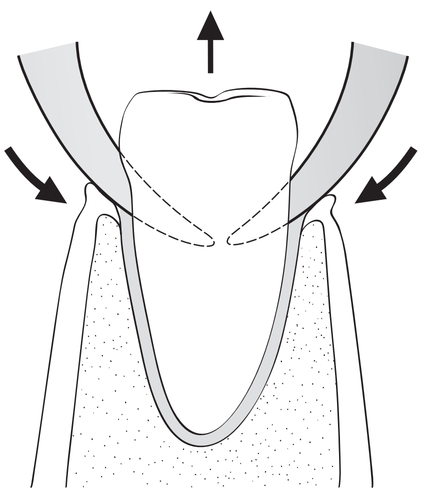


Figure 5.10 Where the crown of a mandibular molar is extensively destroyed, the use of Cow Horn forceps may allow an extraction to be completed routinely, thus a surgical procedure can be avoided. The sharp, curved buccal and lingual beaks are positioned between the mesial and distal roots. As the handles of the forceps are closed, the beaks are squeezed further into the bifurcation and produce a tractional force which expels the tooth from its socket. Subsequent buccolingual movements allow the tooth to be lifted from its socket.

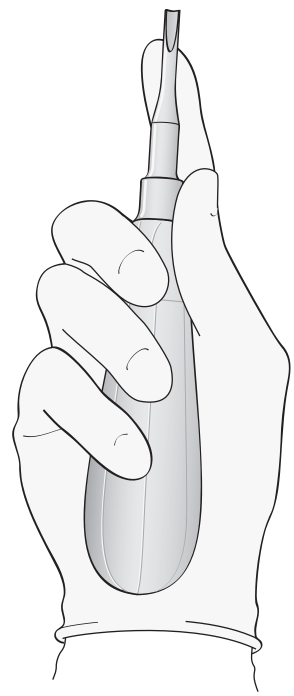


Figure 5.11 Operator's index finger is extended along the length of the elevator.

apical position. Their subsequent rotation then luxates and promotes the displacement of the tooth, with a minimum of force and alveolar destruction.

Periotomes

Periotomes are instruments that are used to sever the soft-tissue attachment of a tooth. They resemble fine straight elevators, but have sharp, narrow blades for cutting. Straight periotomes are used for single-rooted teeth whilst angled ones are appropriate for multi-rooted teeth. They are inserted into the periodontal space and with apical pressure are moved from the distal to the mesial aspect of a tooth or root; first buccally and then palatally. By severing the soft-tissue attachment in this way, there is less need for vigorous manipulation of the tooth within its socket during the extraction. Alveolar expansion and damage are therefore minimized. Patients who have received treatment with bisphosphonate or other antiresorptive medication and those for who implant treatment is planned will benefit from the use of periotomes prior to an atraumatic forceps extraction.

NON-SURGICAL REMOVAL OF ROOTS

Where the crown of a tooth is largely absent, attempts can be made to remove it without a surgical procedure which will minimize unpleasant post-operative sequelae such as pain and swelling. Using alveolar bone to act as a fulcrum to apply forces to the root, luxators or elevators may be used to displace roots from their sockets. Luxators are particularly effective in this situation.

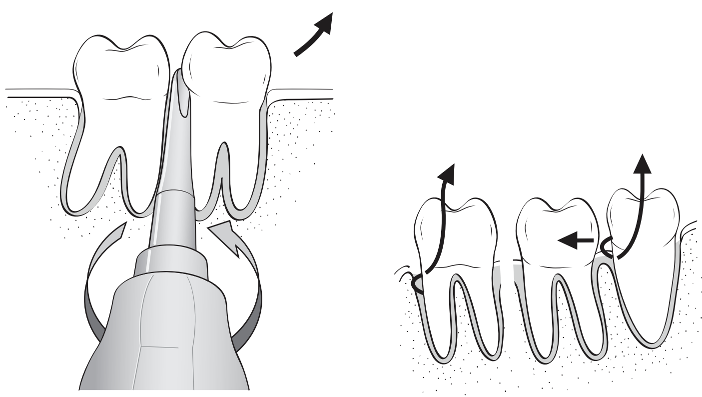
Single-rooted teeth: The instrument should be inserted between the mesial and distal aspects of the root surface and alveolar bone. By rotating it, the root becomes mobilized ready for delivery by forceps or displaced out of the socket (Figure 5.13).

Multi-rooted teeth: Where a multi-rooted molar with a destroyed crown must be removed, elevation alone may be fruitless and not result in delivery of the tooth. In this situation, the roots may be divided with the use of a water-cooled bur (Figure 5.14) or by rotating a straight elevator in the bifurcation (Figure 5.15). The separated roots are subsequently elevated or removed with forceps.

TRANSALVEOLAR, SURGICAL EXTRACTION

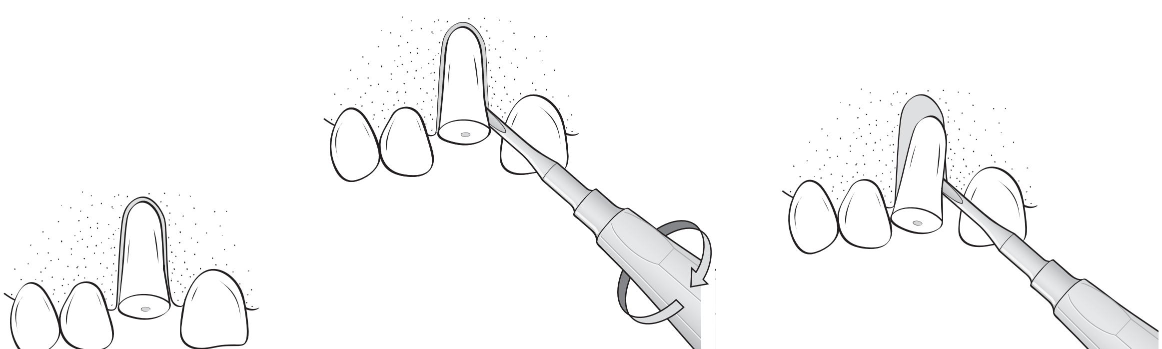
The surgical removal of teeth using a traditional transalveolar approach utilizes the benefits of improved access and visibility afforded by raising a mucoperiosteal flap. The removal of alveolar bone and tooth division may also be necessary. Extensive coronal destruction, unusual root morphology, unfavourable root pattern, ankylosed or dilacerated roots are predictive of the need for a surgical extraction.

The aim of the surgical approach is to deliver a tooth or its remnants along a surgically created pathway. The first step involves the raising of a mucoperiosteal flap. An incision is made through the mucoperiosteum, allowing the site of surgery to be exposed. The incision defining the flap should be full thickness, placed over bone not planned for removal and distant from adjacent vital structures. A horizontal element around the gingival margin and vertical relieving incision buccally are usually indicated, with inclusion of the gingival papilla within the flap. Ensuring that the base of the flap is wider than the gingival aspect,



(a) (b)

Figure 5.12 (a) The elevator produces a force which luxates the tooth, displacing it out of its socket. (b) An equal force will also be applied to the fulcrum.



(a) (b) (c)

Figure 5.13 (a–c) Elevation of a root.

careful manipulation and effective closure of the soft tissues optimizes the vitality and healing of the flap. Where visualization of the surgical site is still difficult, the provision of a further relieving incision to create a three-sided flap improves both this and surgical access (Figure 5.16).

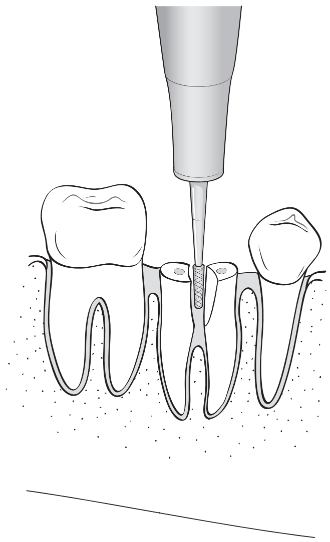


Figure 5.14 Division of a multi-rooted tooth with a bur.

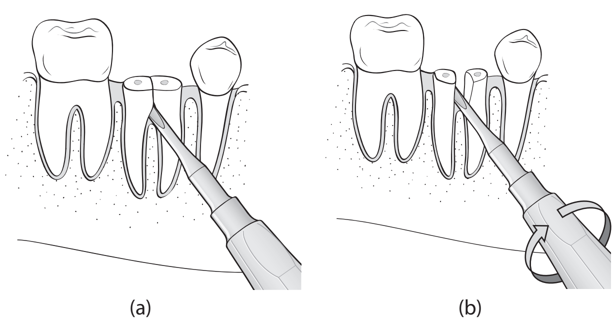


Figure 5.15 Division of a multi-rooted tooth using an elevator.

Having exposed a tooth, the improved access and direct vision may allow it to be elevated or removed with forceps with no need for bone removal (Figure 5.17).

The removal of bone from around the tooth is, however, often necessary. Tungsten carbide tipped round or fissure burs with water coolant are usually used. Creation of a bony gutter on the buccal aspect of a tooth reduces its support making it easier to displace, provides a point of application for elevators and exposes it sufficiently to facilitate its surgical division. Bone removal along the tooth's mesial–distal length should expose the root surface and produce a deep but narrow cut which may be engaged effectively by elevators (Figure 5.18).

A multi-rooted tooth may resist being elevated intact from the alveolus even after bone removal. It may have roots with no common path of withdrawal and surgical division is then indicated. This procedure allows the tooth to be removed in smaller constituent parts, bone is therefore preserved and the forces needed to complete the extraction are reduced. Maxillary molars have buccal roots which may be divided from the palatal root and each other if necessary (Figure 5.19).

Mandibular molars may be divided with one buccolingual cut (Figure 5.20).

Bone removal to expose the bifurcation of a tooth and subsequent use of a bur to cut from the bifurcation in an occlusal direction allows a greater degree of certainty that the roots will be effectively separated than when a cut is made blind from the occlusal surface towards the bifurcation. Decoronation prior to surgically dividing a tooth may further maximize the chance of successful section. It is often desirable to avoid cutting right through the root mass, instead the bur can be used to divide two thirds of the way through the tooth and then the remainder split by rotating a narrow, straight elevator within the cut. Such surgical division is usually sufficient to allow the tooth to be removed; however, in other cases, the separated roots may still resist removal. Bone removal around each of them will then be necessary.

Following bone removal and tooth division, straight dental elevators of increasing size can be used to luxate and remove the tooth or its separated root fragments.

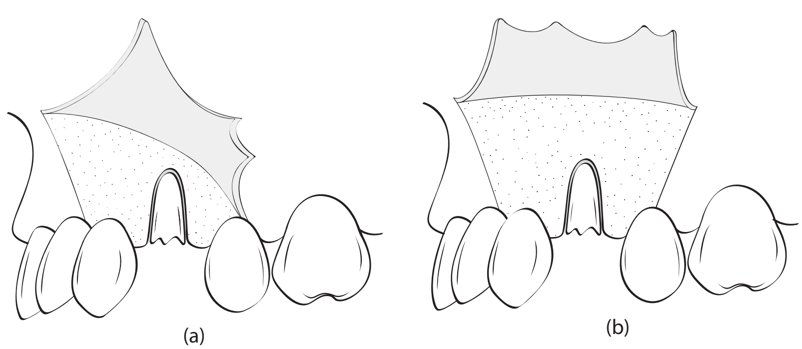


Figure 5.16 (a) Three-sided flap produced by a gingival and one relieving incision. (b) Further relieving incision creates a four-sided flap.

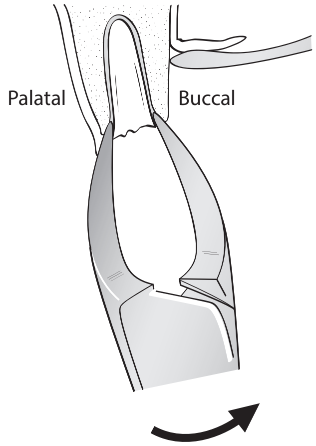


Figure 5.17 Removal of a root with forceps following the reflection of a mucoperiosteal flap.

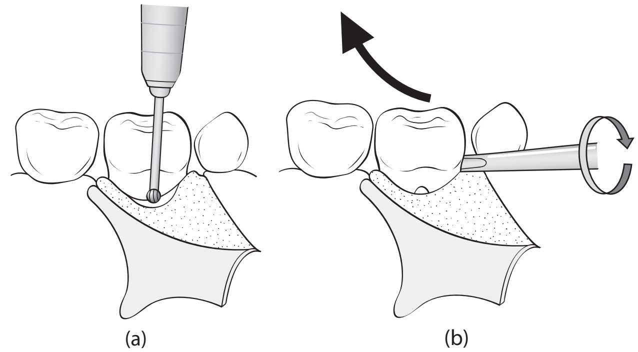


Figure 5.18 (a) Bone removal to expose the root surface and produce a gutter buccally. (b) Use of elevators at the point of application to displace a tooth.

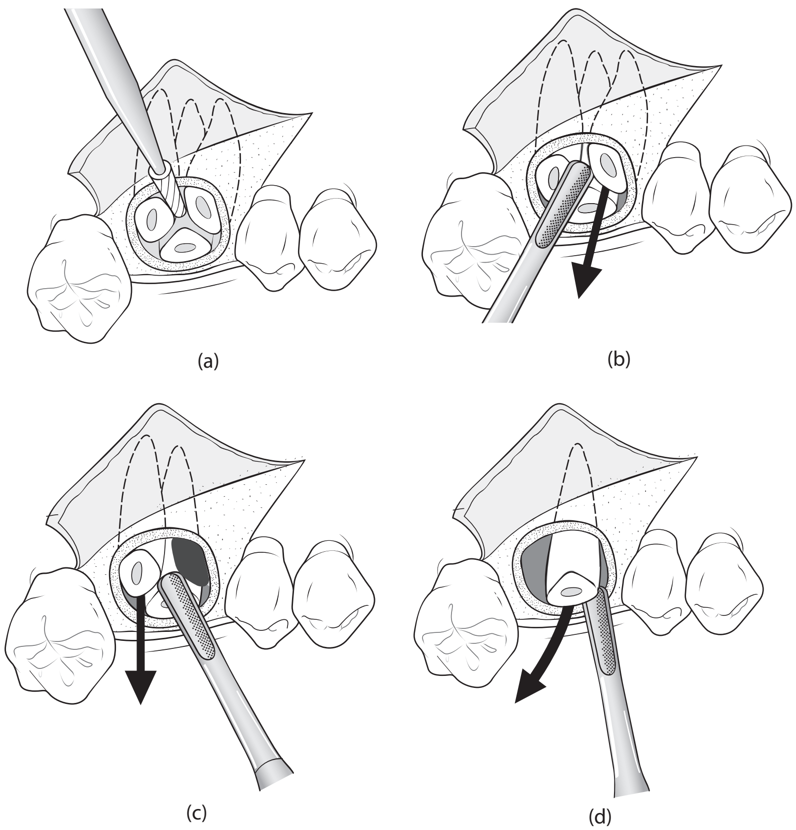


Figure 5.19 (a–d) Division and elevation of the roots of a maxillary molar.

Force should be applied mesially and buccally in the long axis of the tooth. Clinical experience brings with it the ability to generate, identify and use a point of application to its full advantage. An effective technique when applying a force to elevate a tooth is also essential.

The use of a sharp-ended Cryer's (East–West) elevator to remove a root of a multi-rooted tooth following extraction of an adjacent one is valuable. The sharp end is introduced to the depth of the socket generated by the removal of the first root and is used to engage the inter-radicular bone and remaining root. A rotational movement is produced as the handle is rotated, allowing the root to be removed (Figure 5.21).

Following the removal of a tooth or its constituent fragments thorough debridement and closure of the surgical defect complete the procedure.

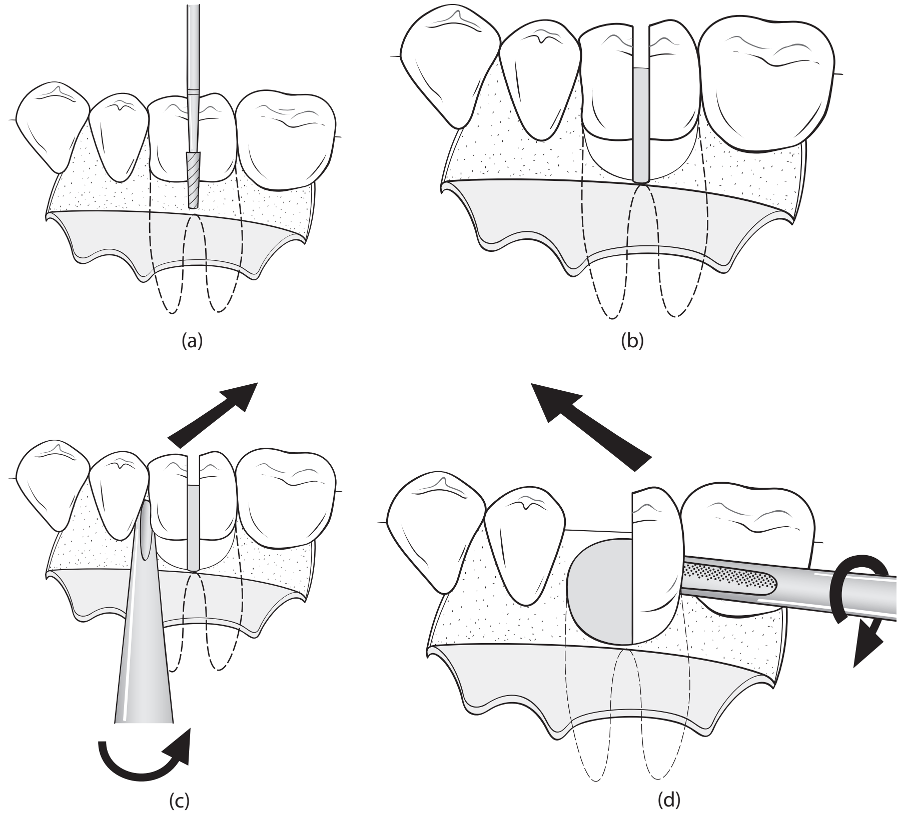


Figure 5.20 (a–d) Division and elevation of the roots of a mandibular molar.

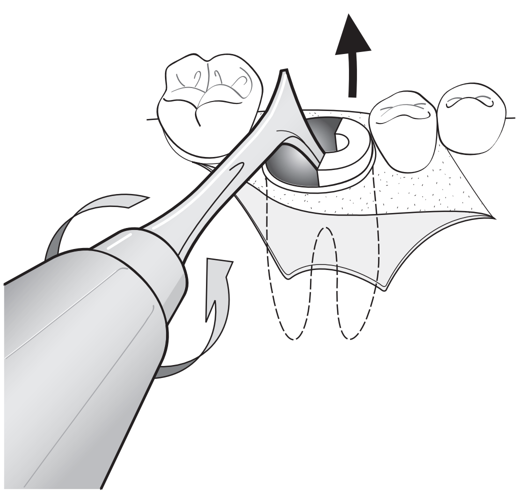


Figure 5.21 Use of a Cryer's elevator to engage and displace a retained root.

'Flapless' surgical extraction

In recent years, an increased appreciation of the benefits of preserving both bone and soft tissue at extraction sites where implant placement is planned has resulted in a greater general awareness of the benefits of optimizing alveolar and mucosal contour for all patients following dental extraction. Therefore, there has been shift away from the traditional surgical exodontia of multi-rooted teeth involving mucoperiosteal flaps and buccal bone removal towards a more conservative approach. When there is resistance to a forceps extraction (often attributable to unfavourable root morphology) rather than progressing to a conventional transalveolar approach, the sectioning or surgical division of the tooth will usually facilitate its removal without the need to raise a flap. This technique can be used to extract maxillary and mandibular molars or multi-rooted premolar teeth. Although the outcome is not as predictable as when a flap is raised, in experienced hands this technique may, however, offer the benefits of tissue preservation.

The removal of the coronal portion of the tooth prior to root division is not essential although this does provide an axial view of the root anatomy which permits the surgeon to divide the remaining roots at the correct location and angulation. Decoronation and the sectioning of roots in their long axis is best achieved with a narrow fissure bur, a straight elevator or luxator can then be inserted into the cut made and rotated to deliver the component parts.

RETRIEVAL OF RETAINED ROOT TIPS

Where a small portion of a root is retained and resistant to removal with an elevator, curette, probe or root pick, an assessment of whether it may be left in situ should be made.

If its removal is indicated then a surgical procedure must be undertaken. The conventional technique of raising a buccal flap, removing bone to expose the root and deliver it may be utilized; however, this is a relatively destructive procedure. Alternatively, a more minimal technique where a soft-tissue flap is raised but the bulk of the buccal plate is preserved may be preferred. This involves creating only a small fenestration in the buccal plate at the anticipated site of the retained root allowing an instrument to be inserted through it to displace the root coronally (Figure 5.22).

MULTIPLE EXTRACTIONS

The number of extractions that can be performed on one occasion is determined by the patient's cooperation, local anaesthetic dose and surgical difficulty. Maxillary extractions should be performed prior to those in the mandible to avoid debris from the former contaminating mandibular sockets. Posterior teeth should be removed prior to anterior ones in the same arch so that there is no obscuring of the view of the former by bleeding anteriorly. The use of papillary sutures to re-appose mucosal tissue allows better soft-tissue healing and contour post-operatively, since the mucosa may gape even without the creation of surgical flaps.

DECIDUOUS EXTRACTIONS

The principles of extracting deciduous teeth are essentially the same as those for permanent teeth; however, there are some differences to consider. First, the unerupted permanent successor of the deciduous tooth being removed is likely to be in close proximity and as this erupts, the roots of the deciduous tooth become resorbed. Thus, the risk of inadvertently removing the developing permanent tooth with the deciduous tooth increases as the permanent tooth moves occlusally. It is therefore particularly important that smaller, deciduous, extraction forceps are applied to deciduous molar teeth either mesial or distal to but not within its bifurcation (Figure 5.23).

A second modification of technique is needed to reflect the fact that the roots of deciduous molars are divergent, relatively long and fragile. They are therefore prone to fracture during extraction resulting in retained fragments close to the developing crown of the successor. When this occurs, the remnants should be removed very carefully with the application of elevators to the mesial aspect of the mesial root and the distal aspect of the distal root only, thus avoiding the region of the bifurcation (Figure 5.24).

POST-EXTRACTION CARE

On completion of a dental extraction, the surgeon assumes responsibility for the patient's aftercare. Both verbal and written instructions should be given, explaining how the extraction site should be cared for, how to avoid precipitating bleeding and what to do should this occur. Responsible surgical practice requires the operator to prescribe suitable and effective post-operative analgesia for the patient as it is almost inevitable that pain will ensue.

The nonsteroidal anti-inflammatory drugs (NSAIDs) have been shown to be highly effective in controlling acute pain following oral surgery. Of this group of drugs, ibuprofen is associated with the lowest incidence of side effects and 400 mg controls this type of pain more effectively than 10 mg morphine intramuscular or 1 g paracetamol taken orally, although emerging evidence suggests that combined drugs containing both ibuprofen and paracetamol are superior to either single drug. Patients for whom the prescription of ibuprofen is contraindicated will benefit from a paracetamol containing analgesic.

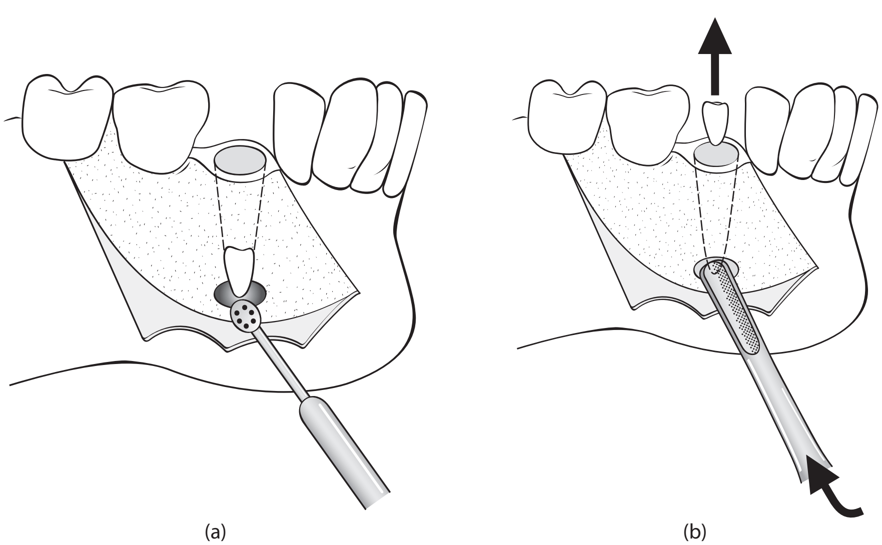


Figure 5.22 (a) and (b) Retrieval of a retained root tip using a bone preserving technique.

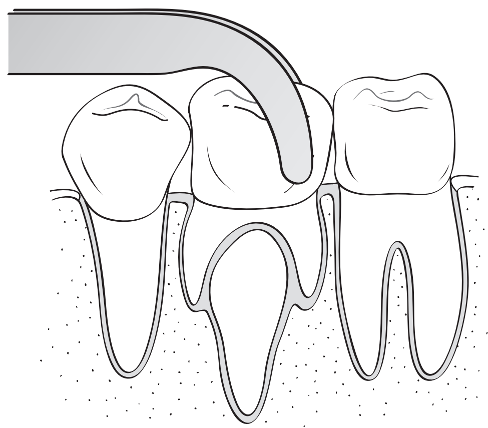


Figure 5.23 Application of forceps to a deciduous mandibular molar away from the bifurcation.

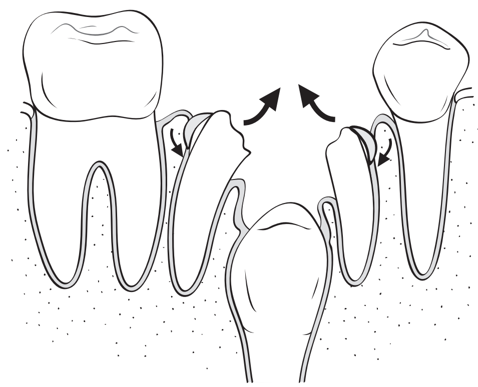


Figure 5.24 Elevation of the roots of a deciduous mandibular molar away from the bifurcation.

COMPLICATIONS

Careful pre-operative planning, an atraumatic surgical technique and attention to post-operative instructions will minimize the occurrence of complications following dental extraction. A patient must, however, be warned pre-operatively of those occurring commonly and sequelae such as pain, swelling and limited mouth opening should be expected. More significant complications are unusual but include post-extraction haemorrhage and alveolar osteitis.

Under normal circumstances, following a dental extraction, a socket should stop bleeding in less than 10 minutes. When a patient presents with post-extraction haemorrhage contributory systemic factors should be excluded. The mouth should then be cleaned thoroughly and the bleeding point identified (good illumination and suction will be required). Local pressure will usually control the bleeding; this can be aided by the insertion of a haemostatic agent such as oxidized cellulose. Control of persistent haemorrhage may require the administration of local anaesthesia, placement of sutures, diathermy or ligation of vessels. Packing ribbon gauze, pre-soaked in Whitehead's varnish into a socket usually achieves haemostasis when other means fail.

Alveolar osteitis (dry socket) is an acutely painful condition which can complicate dental extractions. It is characterized by the onset of pain 24–72 hours post-operatively. Examination reveals halitosis, erythema of surrounding soft tissues and an exposed bony socket from which the clot has been lost and which has often become filled with debris. Treatment involves debridement of the socket into which an antiseptic, obtundant dressing should be placed and the prescription of analgesia. Recent systematic reviews have examined the efficacy of therapeutic interventions undertaken to reduce the incidence of alveolar osteitis after oral surgery. These demonstrated that mouth washing with chlorhexidine pre-operatively and then for 7 days post-operatively and the placement of chlorhexidine gel into sockets immediately following extraction are both effective in reducing the occurrence of alveolar osteitis, although clinicians should be aware of the possibility of anaphylaxis as a result of such topical use of chlorhexidine products. There is no evidence to support the prescription of antibiotics to prevent alveolar osteitis or post-operative infection following dental extraction in healthy patients.

Top tips

- During an extraction, the proper positioning of the patient and operator ensures that both are comfortable and that the forces applied to the tooth are mechanically efficient.
- Attempts to remove a tooth by using elevators and forceps when pre-operative evaluation suggests that a surgical procedure should be undertaken will be excessively traumatic and will prolong the procedure.
- The use of periotomes and luxators and the minimization of bone removal will preserve vital tissue and optimize outcome.
- When using an elevator, the blade must be positioned correctly between the root and alveolar bone and not between two teeth as this will mobilize and displace both.
- The generation of excessive force whilst using elevators or forceps should be avoided as this predisposes to the fracture of the tooth or alveolus.
- The surgical division of a tooth without raising a mucoperiosteal flap minimizes post-operative discomfort and preserves both bone and keratinized soft tissue at the extraction site.
- Mucoperiosteal flap design should provide optimal access and visualization of the surgical site whilst limiting the extent of surgical trauma.
- Buccal bone removal to create a narrow gutter adjacent to a tooth reduces its bony support whilst preserving a ridge of buccal cortex which then provides a fulcrum for the subsequent elevation of the tooth.
- Most complications result from inadequate pre-operative evaluation and poor surgical technique.

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6

Removal of unerupted teeth

CATHERINE BRYANT and CLARE GLEESON

CONTENTS

INTRODUCTION

An unerupted tooth is one that has not emerged through the oral mucosa into the oral cavity at a developmental stage when this would usually have been expected. In most cases, such failure of eruption is the result of impaction where ectopia or an identifiable barrier (e.g. lack of space, a supernumerary tooth, odontome or cyst) prevents the normal eruption of a tooth. Less commonly, eruption ceases before the tooth emerges through the oral mucosa with no identifiable barrier to eruption, a situation referred to as primary retention. After third molars, the maxillary canines and mandibular premolars are the teeth that most frequently remain unerupted. Supernumerary teeth, most commonly seen in the anterior maxilla or mandibular premolar region, also tend to remain unerupted.

The surgical removal of an unerupted tooth may be indicated if its retention will interfere with the orthodontic alignment of adjacent teeth, if there is associated pathology or if the presence of the unerupted tooth is adversely affecting adjacent teeth. If there is no indication to remove an unerupted tooth then this can be left in situ, provided that it is monitored clinically and radiographically (at appropriate intervals) to ensure that pathological change does not develop.

The principles of completing an extraction with minimal loss of vital tissue whilst avoiding iatrogenic damage to adjacent structures have been discussed in Chapter 5 and are as relevant, perhaps more so, during the surgical removal of unerupted teeth.

PRE-OPERATIVE EVALUATION

The presence of an unerupted tooth should be suspected when a permanent tooth fails to erupt within 6 months of its contralateral counterpart, if there is prolonged retention of primary teeth or where a localized malocclusion is accompanied by a 'missing tooth'. Clinical examination will confirm which teeth of the normal series are unerupted and may suggest the reason for this if crowding, abnormally fibrous soft tissue or a dental anomaly are contributory. Palpation of the alveolus may allow the surgeon to determine the bucco-palatal position of the unerupted tooth, particularly if it is in a superficial position, but may be unproductive or unreliable. Radiographic assessment is essential prior to the surgical removal of an unerupted tooth to ensure that the surgeon has a clear understanding of its position, relationship to adjacent teeth and other vital structures such as the maxillary sinus or mental and inferior alveolar nerves (IANs). Panoramic radiography provides a useful overview of the dentition and position of teeth. It can be used in a parallax technique with intra-oral radiographs such as periapical and occlusal views to establish the bucco-palatal position of an unerupted tooth. This is essential when considering the design of the mucoperiosteal flap which will provide the most effective access to the tooth during its removal.

Cone beam computerized tomography (CBCT) provides highly accurate localization of an unerupted tooth in three dimensions and demonstrates resorption, dilaceration, morphology, malformation and proximity to anatomical structures very clearly allowing accurate

pre-operative surgical planning. The surgeon should, however, be aware that the effective radiation dose of CBCT is considerably greater than plain radiography and its use particularly in the younger patients often presenting with unerupted teeth should be considered carefully. UK Ionizing Radiation (Medical Exposure) Regulations (IR(ME)R) and European Commission radiation protection guidance recommends that the use of CBCT in children should be restricted to complex cases in which the benefit of additional diagnostic information obtained outweighs the additional radiation risk. The dose received by the patient should be further minimized by scanning the smallest possible volume size (Figure 6.1).

The importance of identifying that an unerupted tooth is closely related to a sensory nerve which could be damaged during its extraction cannot be understated. A failure to appreciate this and the spacial relationship between tooth and nerve may result in a patient suffering an avoidable permanent post-operative sensory deficit, possibly accompanied by neuropathic pain, which can be functionally disabling in some individuals. Unerupted mandibular canine, premolar and molar teeth present the greatest risk of neuropathy within the distribution of the IAN but the removal of high, unerupted maxillary teeth and the injudicious use of flap retractors high in the buccal sulcus during extractions in the maxillary arch can also disrupt the infraorbital branch of the maxillary nerve. In cases where surgical intervention is unavoidable but CBCT scanning demonstrates an intimate relationship between the root of an unerupted tooth and the inferior dental canal (IDC) suggesting that the surgical removal of the entire tooth would present an increased risk of post-operative neuropathy, coronectomy may be considered. Coronectomy, or partial odontectomy is a conservative surgical technique in which the crown of a tooth is removed but its roots or (root) are deliberately left in situ. In carefully selected cases, this alternative to the complete removal of a tooth may represent the treatment of choice to reduce the risk of post-operative neuropathy (Figure 6.2).

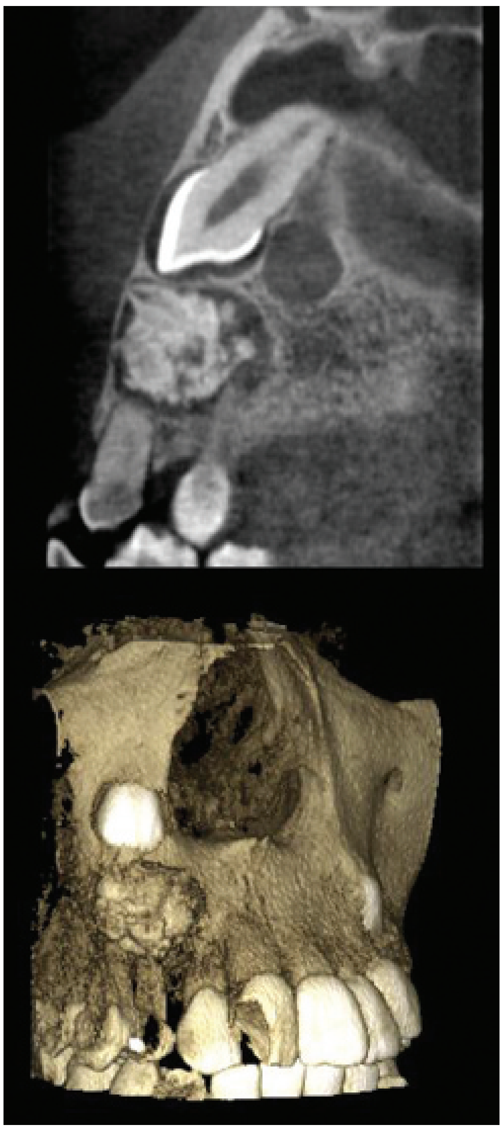


Figure 6.1 Cone beam computerized tomography (CBCT) views of a right maxillary canine tooth that has been prevented from erupting by a compound odontome. The benefits of detailed, three dimensional imaging which this scanning technique provides is clearly demonstrated.

SURGICAL PROCEDURE

Surgical removal – Unerupted maxillary incisor

The surgical removal of a maxillary incisor may be indicated when its eruption has been prevented by an obstruction such as a supernumerary tooth or odontome or when trauma to the primary dentition has resulted in dilaceration of the permanent incisor which cannot be aligned. These teeth are usually accessed using a two-sided buccal flap, the distal relieving incision usually being necessary to expose the incisor which may occupy a very high position in the alveolus. The buccal bone overlying the crowns of these teeth is often very thin and its removal may be achieved with hand instrumentation. If this is not the case, a water-cooled rosehead bur can be used to expose the tooth with care being taken to avoid damage to the roots of the adjacent teeth. Once its crown is exposed, the incisor tooth can usually be elevated from the alveolus without difficulty; however, if there is a significant dilaceration of the root of the tooth, the sectioning and removal of the crown may be required to allow the elevation of the root along a different path of withdrawal (Figure 6.3).

Surgical removal – Unerupted maxillary canine

Maxillary canines may remain unerupted as a result of crowding, ectopia, impaction or an inherited dental

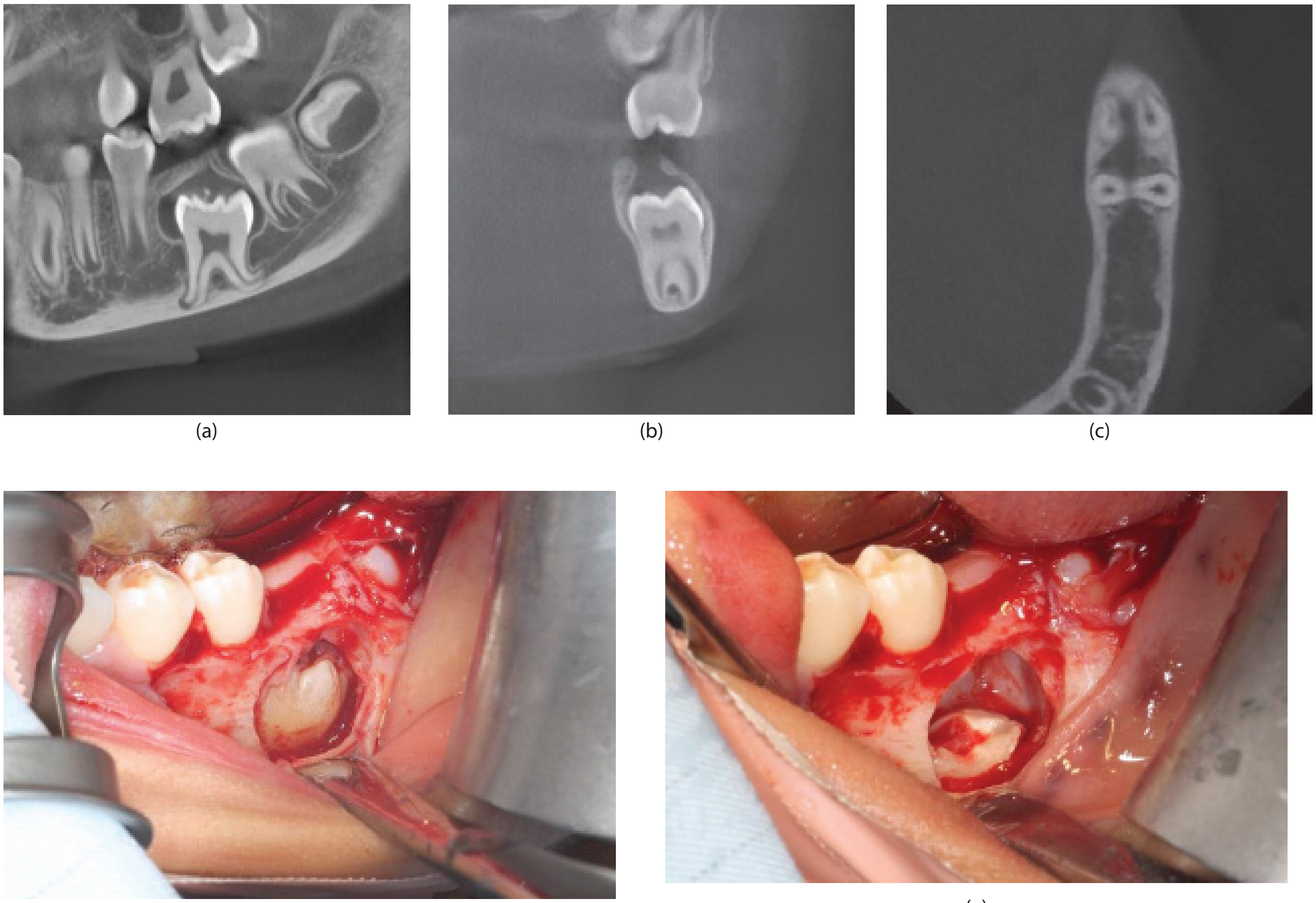


Figure 6.2 Parasagittal (a), coronal (b) and axial (c) CBCT images of an unerupted mandibular left first molar tooth which demonstrates the inferior dental canal (IDC) running between its two buccal and two lingual roots and the surgical procedure to expose (d) and perform a coronectomy on this tooth (e).

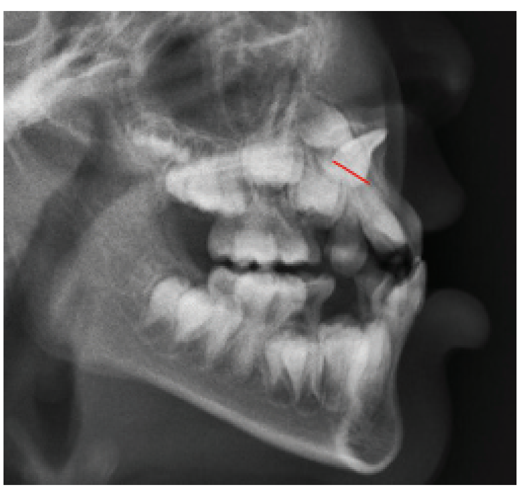


Figure 6.3 Red line indicates the line along which this severely dilacerated central incisor will need to be sectioned to allow its root to be elevated.

anomaly. If the orthodontic alignment of an unerupted canine is not indicated, surgical removal is often requested to prevent later development of cystic change or resorption of adjacent teeth. Buccally placed unerupted canines are usually accessed via a two-sided mucoperiosteal flap comprising a gingival sulcus and distal relieving incision (Figure 6.4).

If, however, the canine occupies a superficial position high in the buccal sulcus where it is easy to locate, a linear incision within the moveable soft tissues just inferior to the tooth can also be used to access the tooth whilst avoiding unnecessary gingival recession around the adjacent teeth (Figure 6.5).

An unerupted palatal canine should be accessed with the use of a palatal flap created by a gingival sulcus incision on the palatal aspect of at least two teeth either side of its anticipated position. Once the soft-tissue flap is retracted, the position of the crown of the unerupted canine will often be revealed by a bulge in or a thinning of the bone overlying it. If this is not the case, a water-cooled rosehead bur can be used to expose the tooth with superficial, sweeping strokes at the indicated site as suggested by imaging to be its most likely location. The sight a soft-tissue dental follicle within the alveolar bone is often the first indication of the position of the underlying tooth. The surgical exposure of the tooth

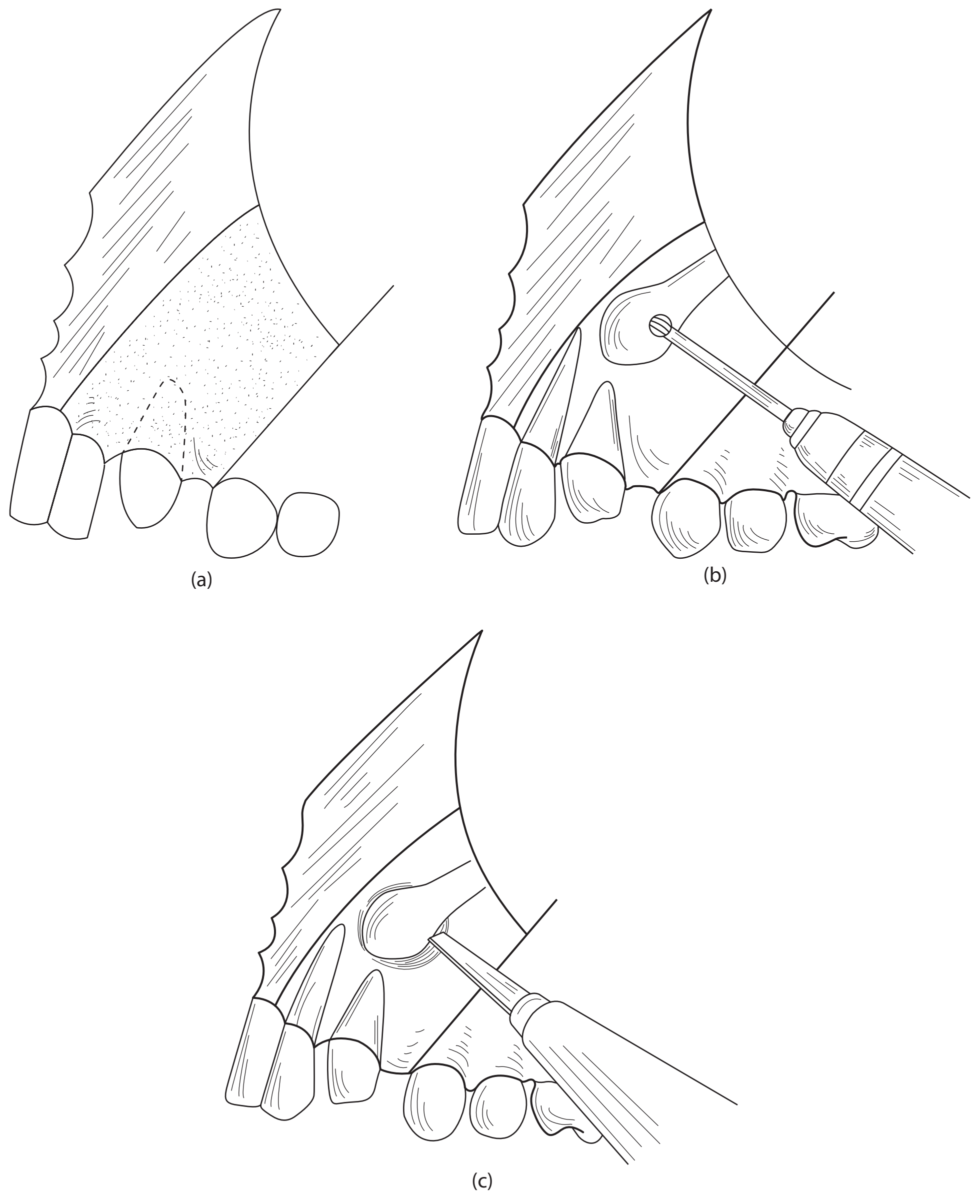
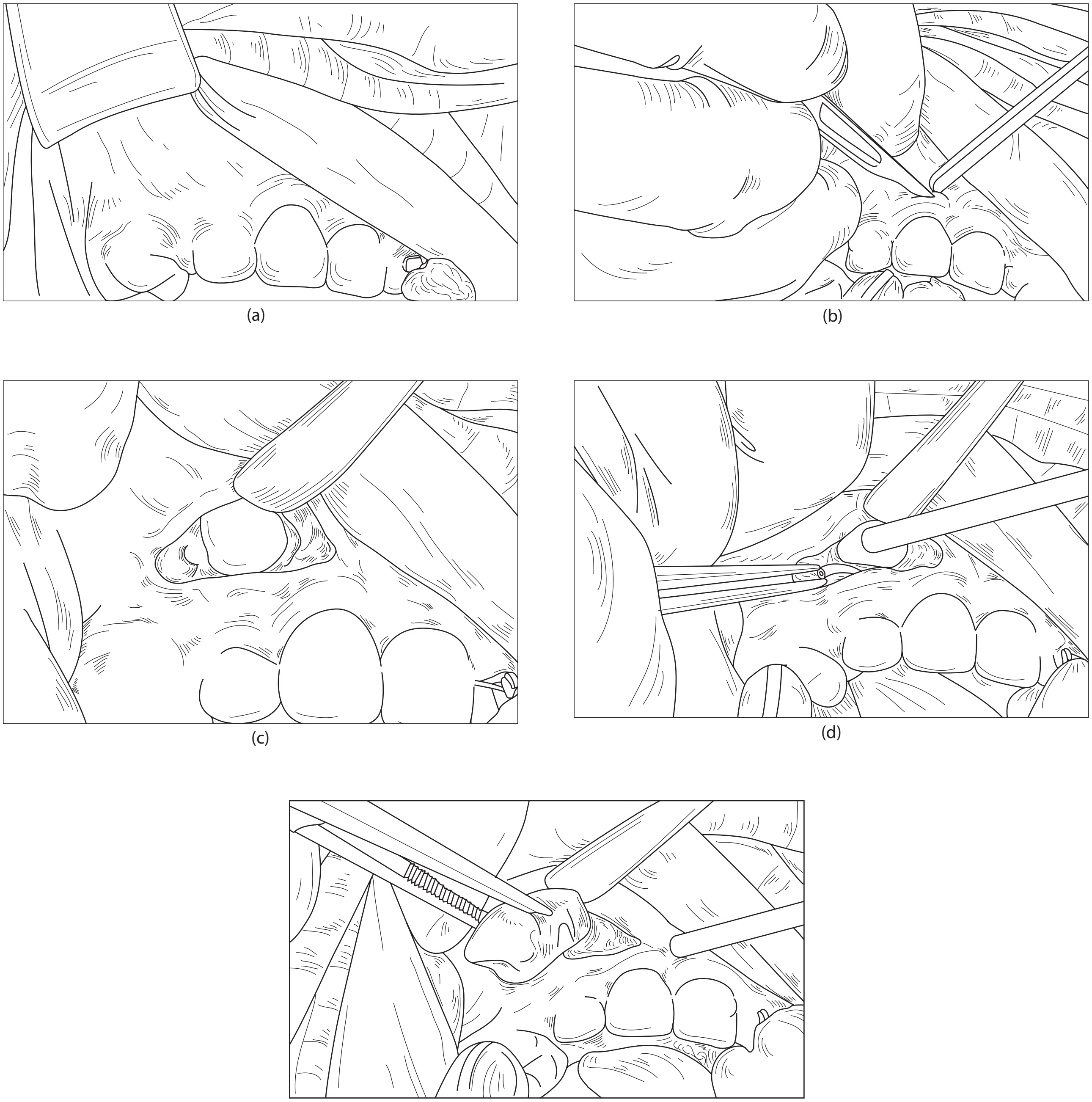


Figure 6.4 Technique for the surgical removal of an unerupted maxillary buccal canine. (a) Two-Sided buccal flap raised. (b) Bone removed to expose crown of unerupted canine. (c) Luxator used to elevate tooth.

should continue until the bone overlying the crown and just beyond the cemento-enamel junction (CEJ) has been removed and an application point for elevators created. Care should be taken not to damage the roots of the adjacent teeth which often lie in close proximity. At this point, the use of a luxator or small elevator on the mesial and distal aspects of the unerupted tooth will often complete the extraction. Care must be taken to ensure that adjacent teeth are not used to provide a fulcrum or these will become mobilized or even displaced. Excessive force should not, therefore, be used and if the tooth resists reasonable force applied, the removal of the crown of the tooth allowing it to be disimpacted from the roots of adjacent teeth will usually allow the root to be delivered successfully (Figure 6.6).

Surgical removal – Unerupted maxillary premolar

Maxillary second premolar teeth may fail to erupt as a consequence of crowding or space loss following the early extraction of primary teeth. These almost always occupy a palatal position, often becoming 'trapped' above the contact point between the first premolar and molar which have become approximated. A palatal flap created by a gingival sulcus incision extended to include at least two teeth either side of the unerupted premolar is used to provide access for the extraction. Once the flap is raised, the premolar is often accessible for the use of a luxator to elevate it. If this is not the case, bone removal to expose the crown usually facilitates its delivery. If resistance to movement is encountered



(a) (b) (c) (d) (e)

Figure 6.5 Technique for the surgical removal of an unerupted high buccal maxillary canine. (a) Pre-operative appearance. (b) Incision made in mobile tissue of buccal sulcus. (c) Crown of unerupted canine exposed. (d) Luxator used to elevate tooth. (e) Canine removed.

or the position of adjacent teeth makes them vulnerable to becoming mobilized when reasonable force is applied, the crown of the premolar should be sectioned from the root to complete the extraction without complication (Figure 6.7).

Surgical removal – Unerupted maxillary molar

The primary retention of maxillary molars or their failure to erupt due to an obstruction (often adjacent teeth) may necessitate their surgical removal. This will usually involve a buccal approach via a two-sided flap to expose the crown of the unerupted tooth. It may then be possible for the tooth to be elevated intact; however, decoronation and the division of roots may be necessary to deliver the tooth and avoid disruption to the adjacent dentition. The surgical removal of a primarily retained first molar which has limited the development of the adjacent alveolus and occupies a superior position close to the floor of the maxillary sinus often creates a communication between the socket and the sinus and care should be taken to achieve

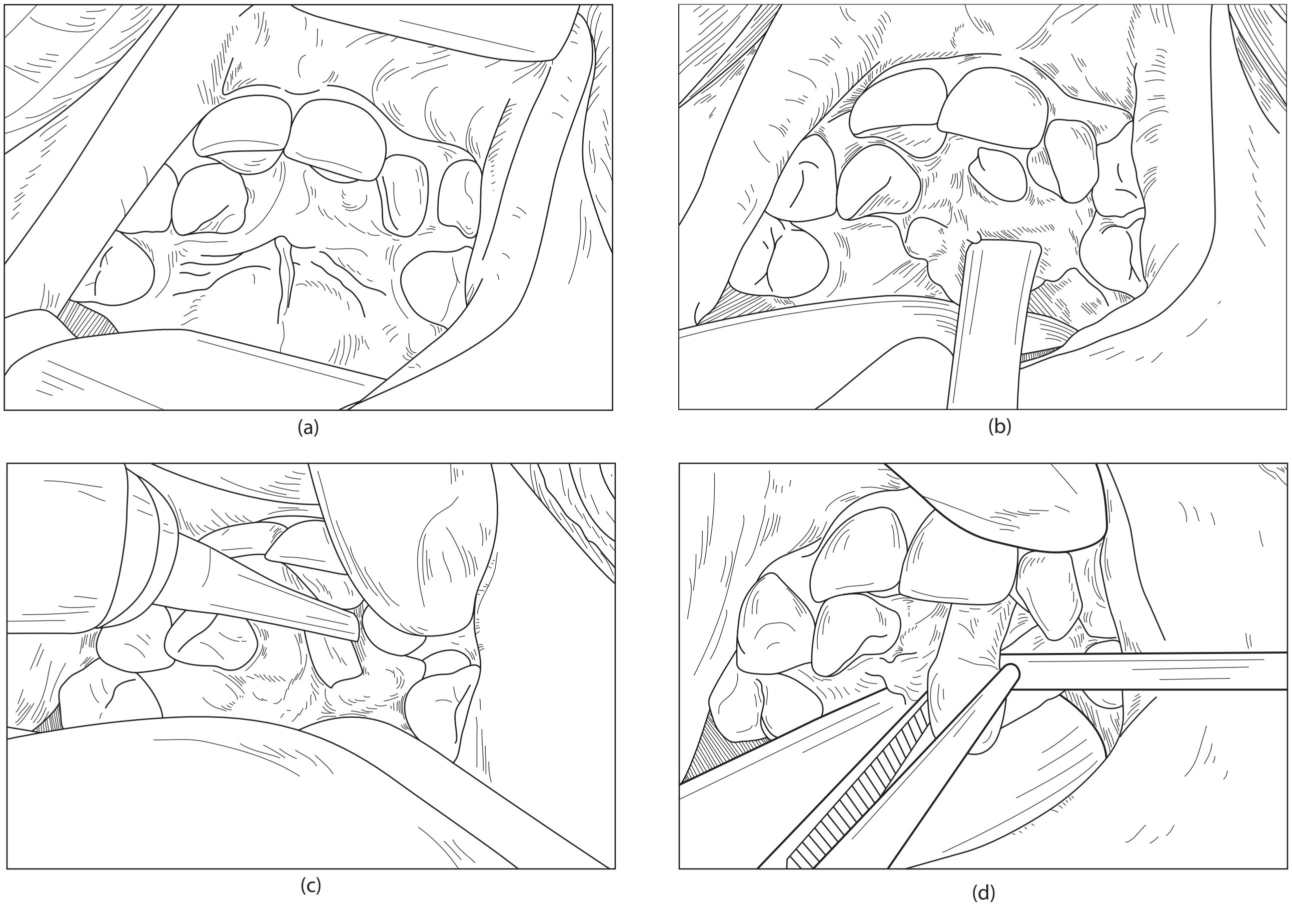


Figure 6.6 Technique for the surgical removal of an unerupted palatal maxillary canine. (a) Pre-operative appearance. (b) Localized palatal flap reflected. (c) Luxator used to elevate tooth. (d) Canine removed.

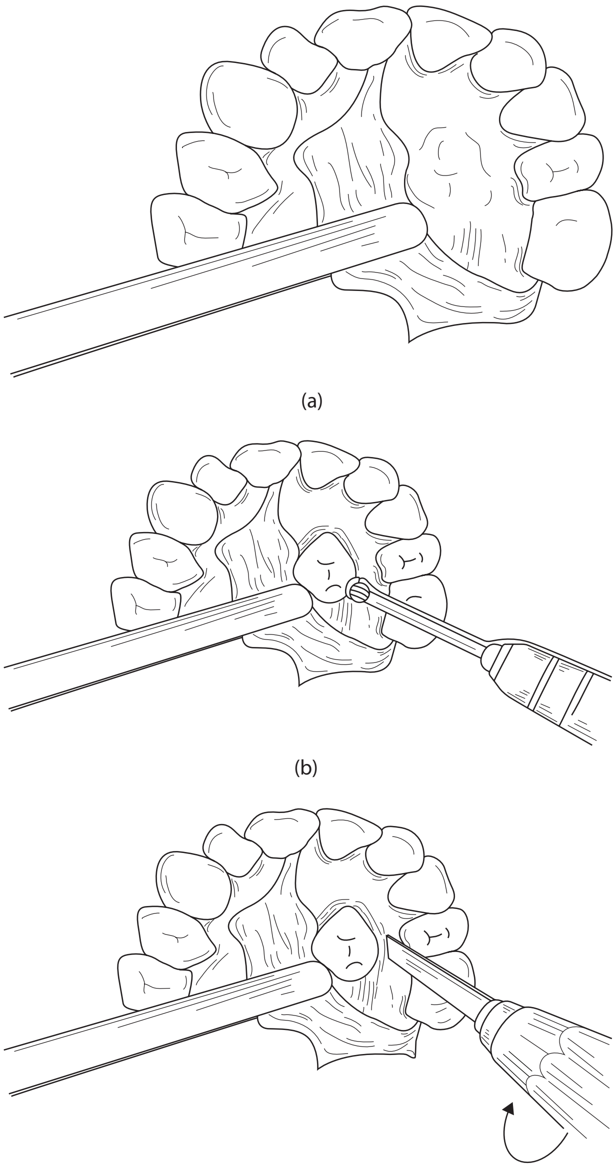
good primary closure and prevent ascending infection (Figure 6.8).

Surgical removal – Unerupted mandibular canine

Mandibular canine teeth may remain unerupted because they are ectopic or because of a lack of space for their relatively late eruption. Surgical removal is achieved by a buccal approach, usually with a two-sided flap. The relieving incision of this flap should be sufficiently mesial to avoid damage the mental nerve as it exits the mandible and to allow subsequent closure of the incision to be supported by intact bone (away from the site of bone and tooth removal). If the crown of the unerupted canine is not visible after a flap has been reflected, a water-cooled rosehead bur should be used to expose the tooth with superficial strokes at the site revealed by available imaging to represent its most likely location in order to minimize damage to adjacent teeth. Once the crown and upper portion of the root have been exposed, it is often possible to deliver the canine tooth with the use of elevators at its mesial and distal aspects. If this is not the case, the tooth should be decoronated to allow the crown and root to be elevated separately. The operator must ensure that the mental nerve which is frequently closely related to the crown of the unerupted canine is protected from compression during the elevation of the tooth or from the use of a flap retractor as both can produce post-operative neuropathy (Figure 6.9).

Surgical removal – Unerupted mandibular premolar

Space loss, obstruction to eruption, over-retained and ankylosed primary teeth or ectopia may cause mandibular premolars to remain unerupted and the removal of these teeth may be indicated. To ensure that an unerupted mandibular premolar is removed as effectively as possible it is essential that the surgeon carefully interprets their clinical findings and the available imaging to ensure that they have a clear understanding of the position of both the crown and the root of the tooth. Not infrequently, unerupted mandibular premolars lie transversely across the alveolar arch with



(a)

(b)

(c)

Figure 6.7 Technique for the surgical removal of an unerupted, palatally displaced maxillary premolar. (a) Localized palatal flap reflected. (b) Bone removed to expose crown of premolar. (c) Luxator used to elevate tooth.

the root apex being located buccally whilst the crown lies lingual to the adjacent teeth. The removal of an unerupted mandibular premolar which lies entirely lingual to the dental arch should be facilitated by raising a lingual flap, created with a single incision in the gingival crevices of the lingual aspect of the teeth adjacent to that being removed. Those unerupted premolars which lie entirely buccal to the arch or transversely across the arch but with the root in a buccal position should be removed with a buccal approach. A two-sided buccal flap is usually required to expose the tooth adequately so care must be taken to ensure that the relieving incision is made well away from the mental nerve. The crown of the premolar is often found to have become 'trapped' within the line of the arch beneath the contact

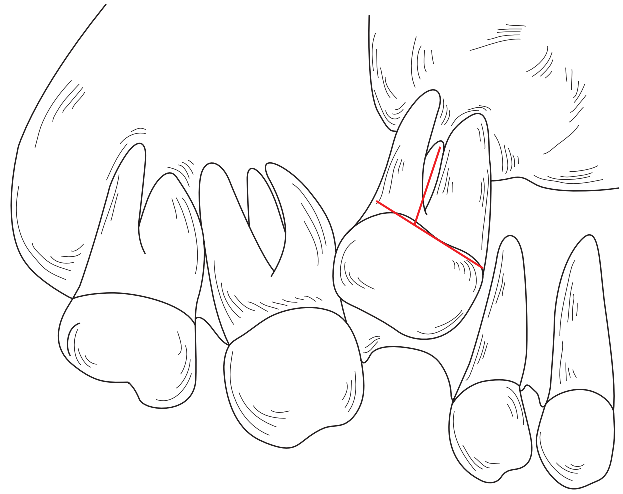


Figure 6.8 Diagram to show the lines along which an unerupted maxillary first molar should be sectioned to effect an atraumatic extraction with minimal disruption to adjacent teeth and the floor of the maxillary sinus.

point of the adjacent tooth which necessitates decoronation in order to allow removal of the crown and then the separated root of the tooth. Occasionally the decoronated crown is too large to be delivered through the limited buccal bony window which can be created between adjacent teeth without being further sectioned itself. Once the crown is delivered, the root of the tooth can usually be elevated without difficulty (Figure 6.10).

Surgical removal – Unerupted mandibular molar

Primary retention or obstructed eruption with subsequent mesial tipping of the tooth distal to it may necessitate the surgical removal of a mandibular first or second molar. Not infrequently, the roots of these teeth have a close relationship to the IAN because of their inferior position within the mandible. Good quality radiographs or ideally CBCT enhance the planning of the surgical procedure to remove such teeth and this is invaluable when circumstances (caries or cystic change) dictate that the unerupted molar has to be completely removed despite a known intimate relationship to the IAN. A two-sided buccal flap will be necessary to adequately expose the crown of the tooth and once again, care must be taken to ensure that the relieving incision is distant from the mental nerve. The tooth should then be decoronated to allow accurate division of its roots (which may have multiple rootlets as a result of apical root development being deflected by the IDC) under direct vision. This atraumatic, elective root division minimizes the risk of IAN injury by reducing the compressive forces transmitted to the nerve from the gentle elevation of the separated roots compared to the heavier forces necessary to deliver the undivided root complex (Figure 6.11).

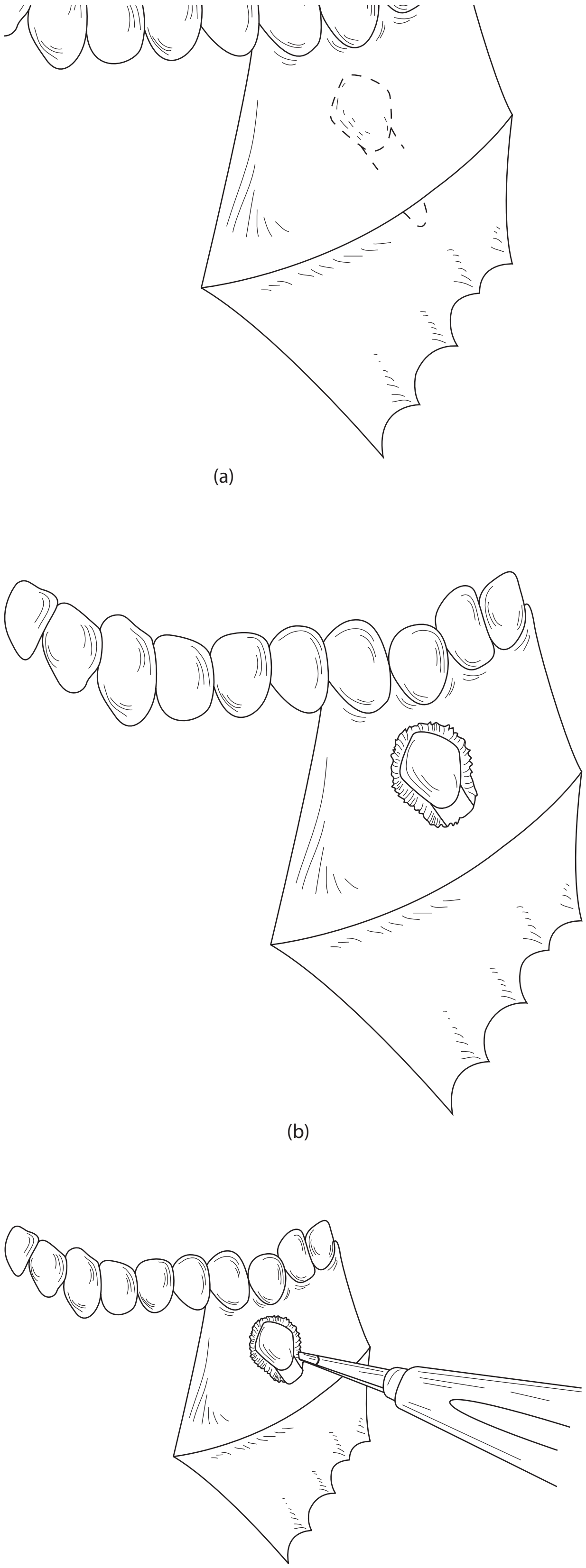


Figure 6.9 Technique for the surgical removal of an unerupted mandibular canine. (a) Buccal flap reflected. (b) Bone removed to expose crown. (c) Luxator used to elevate tooth.

Surgical removal – Unerupted supernumerary teeth

A supernumerary tooth in the upper labial segment is usually located on the palatal aspect of the permanent incisors, which may remain unerupted because of its presence. These supernumerary teeth in the anterior maxilla can be identified and removed via a flap created by making a gingival crevice incision on the palatal aspect of one or two teeth to each side. It is often possible to raise the flap without disruption to the nasopalatine neurovascular bundle as it emerges from the incisive canal, but if this obstructs the removal of the supernumerary it can be divided to improve access with little consequence. The removal of a high, inverted, often conical supernumerary tooth (a 'mesiodens' above and between the roots of the central incisor teeth warrants high-quality imaging, perhaps CBCT, to ensure that this is achieved without excessive bone removal and damage of the adjacent incisor roots, which could result in them becoming non-vital. Although the roots of such supernumerary teeth may lie on the palatal aspect of the incisor roots, their crowns (the widest part) are often superior to the incisor apices and most easily removed with a high buccal approach. It may be possible to elevate the supernumerary tooth intact from the buccal aspect after the overlying bone is removed or if resistance is encountered it can be decoronated and then the root elevated and delivered superiorly (Figure 6.12).

The supernumerary teeth which develop in the mandibular premolar region, occasionally bilaterally, can often be left in situ without problem. Where, however, their removal is indicated, accurate imaging (true occlusal view or CBCT) to establish their bucco-lingual position relative to the adjacent teeth is essential to ensure that the most appropriate flap is raised. This is particularly important if the teeth are in the early stages of development and still small as at this time they can be very difficult to locate clinically without significant bone removal and risk of damage to neighbouring teeth.

THIRD MOLARS

Mandibular third molars

The most common indications for the removal of mandibular third molars (M3Ms) are caries and recurrent episodes of pericoronitis (inflammation of the surrounding operculum) due to incomplete eruption. Unerupted M3Ms may also become associated with cysts or tumours and require removal. In addition to thorough clinical examination, detailed radiographic assessment is essential when treatment planning M3M surgery because of the potential risk of inferior alveolar nerve injury (IANI).

The surgeon should examine the dental panoramic tomogram (DPT) in a stepwise manner to establish the following (Figure 6.13):

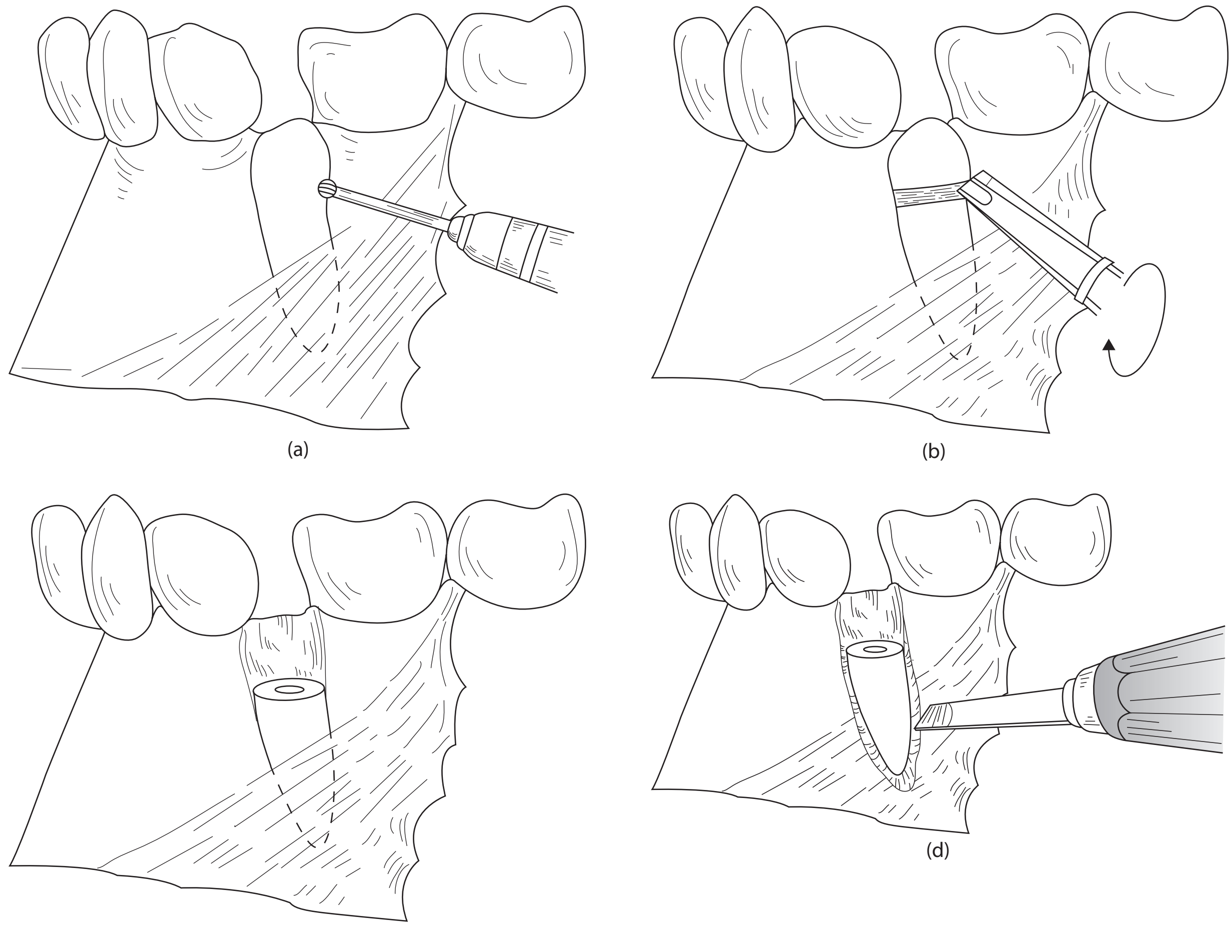


Figure 6.10 Technique for the surgical removal of an unerupted mandibular premolar. (a) Two-Sided buccal flap reflected and premolar exposed. (b) Crown and root divided and elevator used to separate them. (c) Decoronated premolar. (d) Luxator used to elevate root.

1. Angulation of the tooth: Whether mesial, distal, horizontal, vertical or transverse.
2. Depth of impaction: Indicated by the distance from the alveolar crest to the potential application point of an elevator. This provides an appreciation of the amount of bone that will need to be removed during the extraction. The quality or density and quantity of surrounding bone are also important factors to consider. The position of the tooth in relation to the ascending ramus is a further indicator of the extent of bone removal required to facilitate delivery.
3. Coronal morphology and associated pathology: Attention should be paid to the presence of caries or increase in follicular width suggestive of cystic change associated with the M3M. The restorative condition of the adjacent tooth should also be noted as extensive caries or large restorations can pre-dispose to intra-operative damage.
4. Root number, morphology, length and the presence of hypercementosis or ankylosis.
5. Proximity to the IAN: Radiographic signs suggestive of an intimate relationship with the IAN include darkening of the root, loss of the corticated margin of the canal and both deviation and narrowing of the canal. In these situations further investigation with CBCT should be considered (Figure 6.14).

The presence of the high-risk features listed above are not the only indicators for CBCT. It is also important to consider such imaging in cases where plain radiography demonstrates that there are sharp apical curvatures at risk of fracture, long root/IDC contact surface area or where the IAN is likely to be in close proximity to a planned surgical cut. In these circumstances, positional awareness of the IAN is vital in reducing iatrogenic nerve injury.

The proximity of a M3M to the IAN is a very significant factor in the selection of the M3M removal or coronectomy as the surgical intervention of choice for a patient who presents for treatment (Figure 6.15).

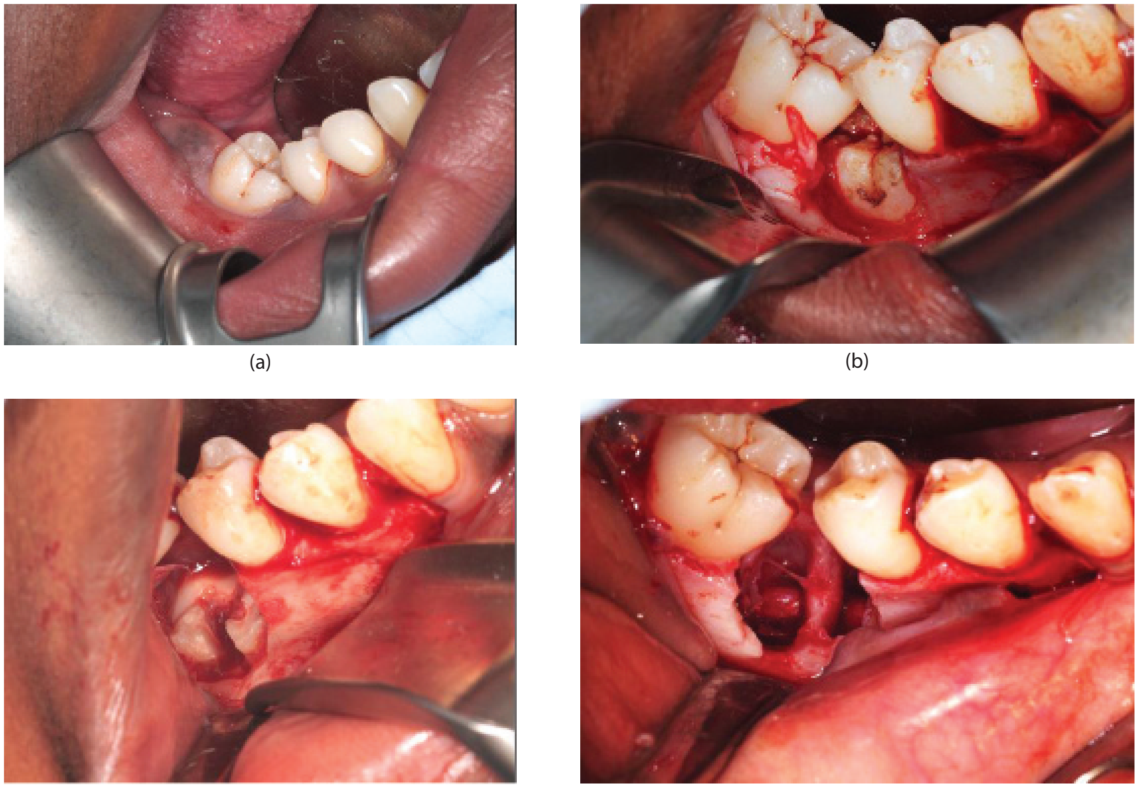

(a) (b) (c) (d)

Figure 6.11 Technique for the surgical removal of an unerupted mandibular first molar. (a) Pre-operative appearance, note absence of permanent first molar. (b) Buccal flap reflected and bone removed to expose crown of tooth. (c) First molar decoronated and mesial/distal roots divided. (d) First molar removed, inferior alveolar nerve (IAN) seen within socket.

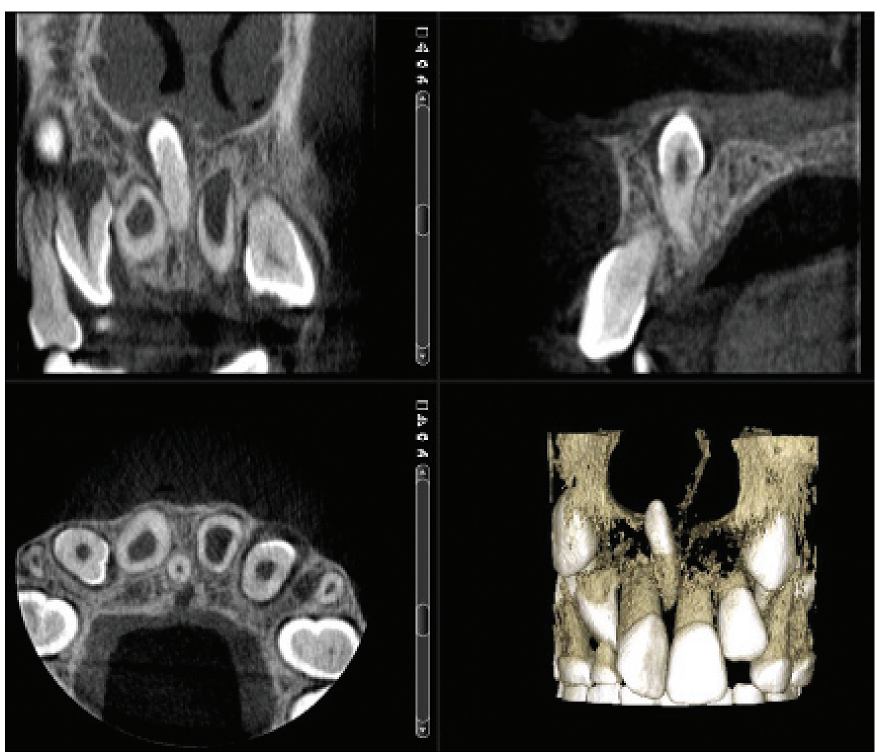


Figure 6.12 CBCT images demonstrating that although the root of this high inverted midline supernumerary tooth lies palatal to the roots of the adjacent incisors, its removal is most effectively achieved via a buccal approach.

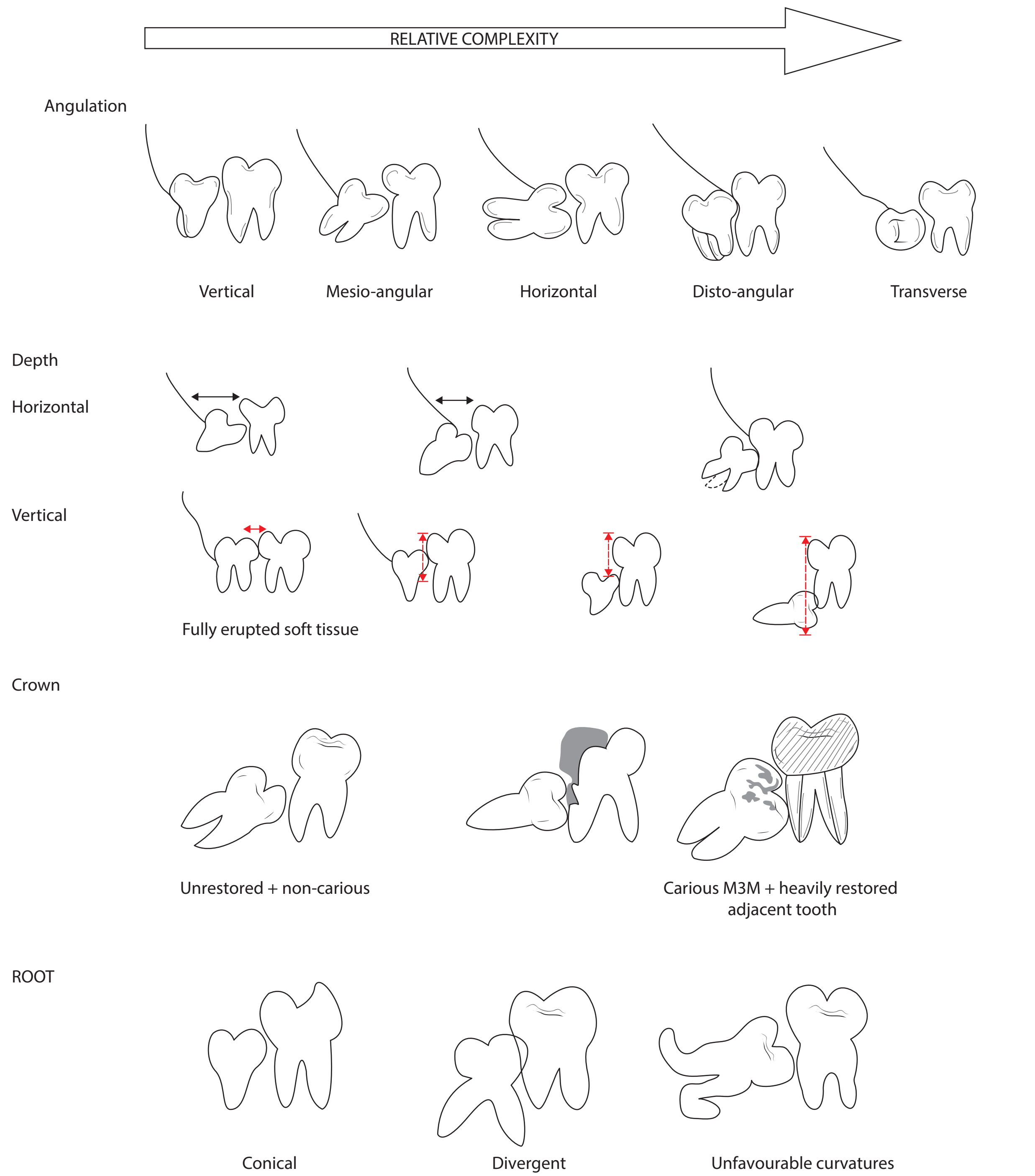


Figure 6.13 Radiographic assessment of an unerupted mandibular third molar (M3M) from a dental panoramic tomogram (DPT).

Surgical removal – Unerupted M3M

A buccal approach is most commonly used with access being dictated by the angulation of impaction and the volume of overlying bone. A vertically soft tissue impacted M3M can be extracted through a minimally invasive single distal relieving incision. When bone removal and sectioning are required, a two-sided full thickness mucoperiosteal 'triangular' flap or envelope flap with distal relief will provide optimal access to the surgical site (Figure 6.16).

In all cases, the posterior or distal relieving incisions should be positioned buccal to the crest of the ridge to avoid transection of lingual nerve which can be superficial. The use of a suitable retractor such as a rake or Minnesota enables atraumatic handling of buccal soft tissues. The use of lingual retraction is not advised unless there is a risk of perforation of the lingual plate or lingual displacement of the tooth.

Bone removal using a water-cooled, sterile rosehead bur should be undertaken to remove sufficient overlying bone

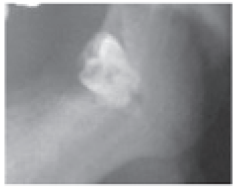
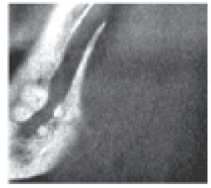
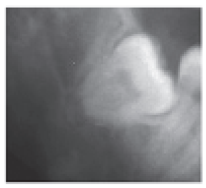
Darkening			DPT displaying darkening of the mesial and distal roots and narrowing of the IDC. The corresponding axial CBCT section shows the IDC weaving through grooving the roots.
Superimposition			DPT displaying superimposition of the IDC over the root mass with corresponding coronal CBCT section showing the IDC positioned buccal to the root mass, with apparent loss of cortication medially.
Deviation			DPT displaying darkening of root apex and narrowing of the IDC with corresponding CBCT section showing IDC passing directly though ('polo minting') the root mass.

Figure 6.14 DPT with corresponding CBCT sections of M3Ms noted to be closely related to the IDC.

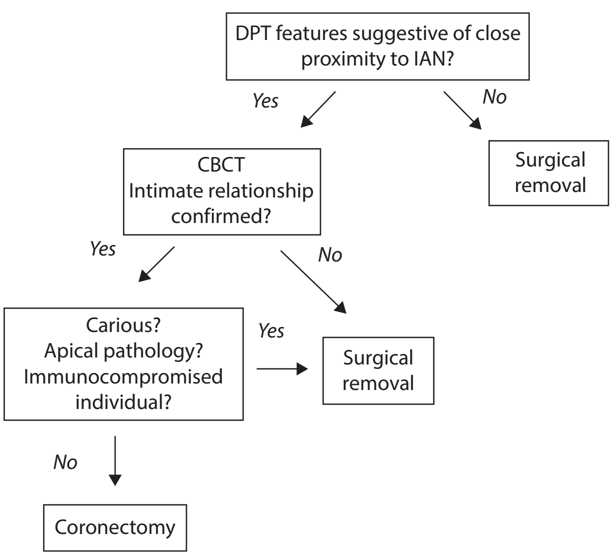
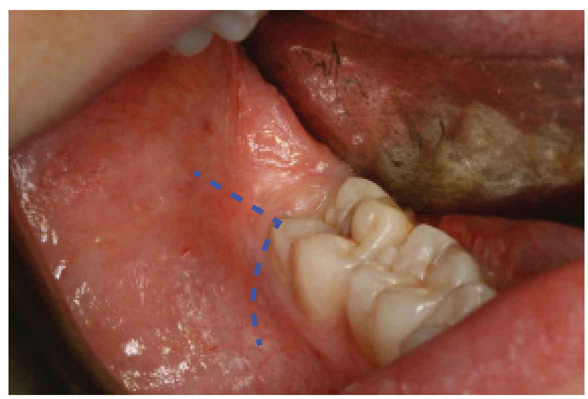
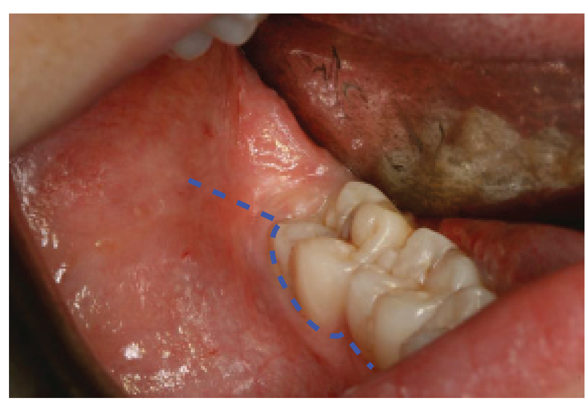


Figure 6.15 Algorithm for the treatment planning of M3Ms.



(a)



(b)

Figure 6.16 Flap design for access to unerupted M3M. (a) Triangular flap. (b) Envelope flap with distal relief.

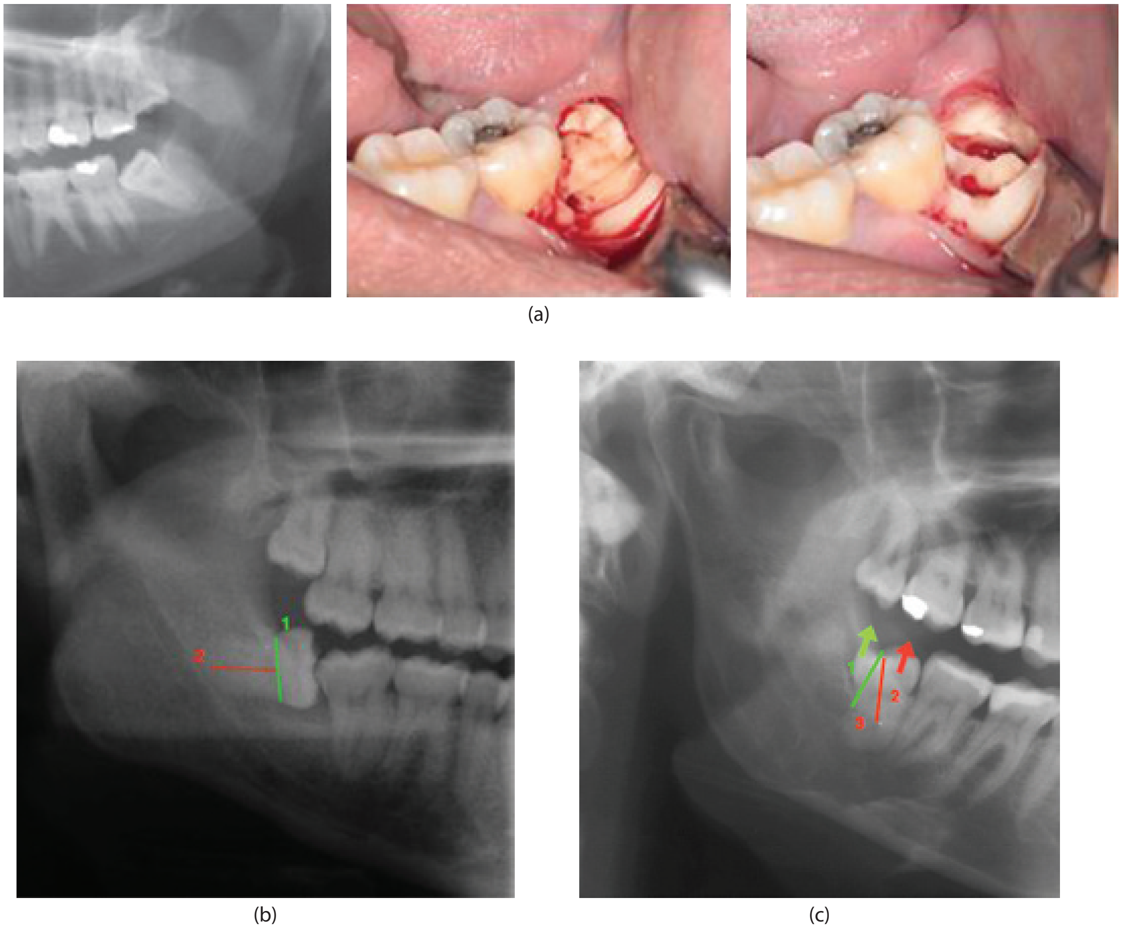


Figure 6.17 (a) Sectioning pattern for a mesioangular M3M, extraction achieved through decoronation and subsequent root division. (b) Sectioning pattern for a horizonal M3M. Care must be taken to ensure the decoronating cut (1) does not undercut the crown which makes it difficult to deliver. Crown removal may require multiple sections. (c) Sectioning pattern for a distoangular M3M. Initial oblique decoronating cut with retrieval of distal portion of impacted crown (1) leaving mesial application point intact. The remaining mesial portion may elevate intact or require root division prior to delivery.

to expose the crown and create an application point. As with all exodontia, every effort should be made to retain as much vital tissue as possible. Decoronation (possibly requiring multiple sections) of the tooth using a fissure bur allows assessment of the pulp morphology and subsequent accurate division of the roots under direct vision (Figure 6.17).

Elective surgical sectioning and elevation of individual roots with light pressure minimizes the transmission of potentially damaging forces to the IAN. Careful reference to pre-operative imaging prior to the sectioning of the M3M will ensure that the cuts are optimally planned and executed, minimizing the risk of iatrogenic IAN injury.

Coronectomy – Unerupted M3M

The use of the technique of coronectomy may be indicated to treat a symptomatic, disease free M3M which is intimately related to the IDC when the complete removal of the tooth would pose risk of iatrogenic IANI (Figure 6.18).

Access to the M3M is achieved by raising a full thickness mucoperiosteal triangular flap which provides sufficient visual and surgical access. Bone removal using a rosehead bur may be required to expose sufficient crown to facilitate sectioning. Bone removal should be limited to the coronal portion of the tooth only and not extended down the root surface. Exposure of the crown allows the decoronating cut to be placed correctly at this level, and minimizes the need for additional enamel removal later. The decoronating cut should be made using a fissure bur perpendicular to the long axis of the tooth. The cut should extend three-fourths of the way across the crown to enable the use of light or fingertip pressure to rotate a couplands chisel or straight Warwick James elevator to displace the crown but avoid transmission of elevating forces to the root mass. The crowns of horizontally impacted teeth may need to be delivered in multiple sections. The retained root should be inspected for signs of mobility and presence of enamel. If enamel is observed this must be removed using a rosehead bur. Finally, the root mass should then be reduced to so that it lies 2–3 mm below bone level and remnants of

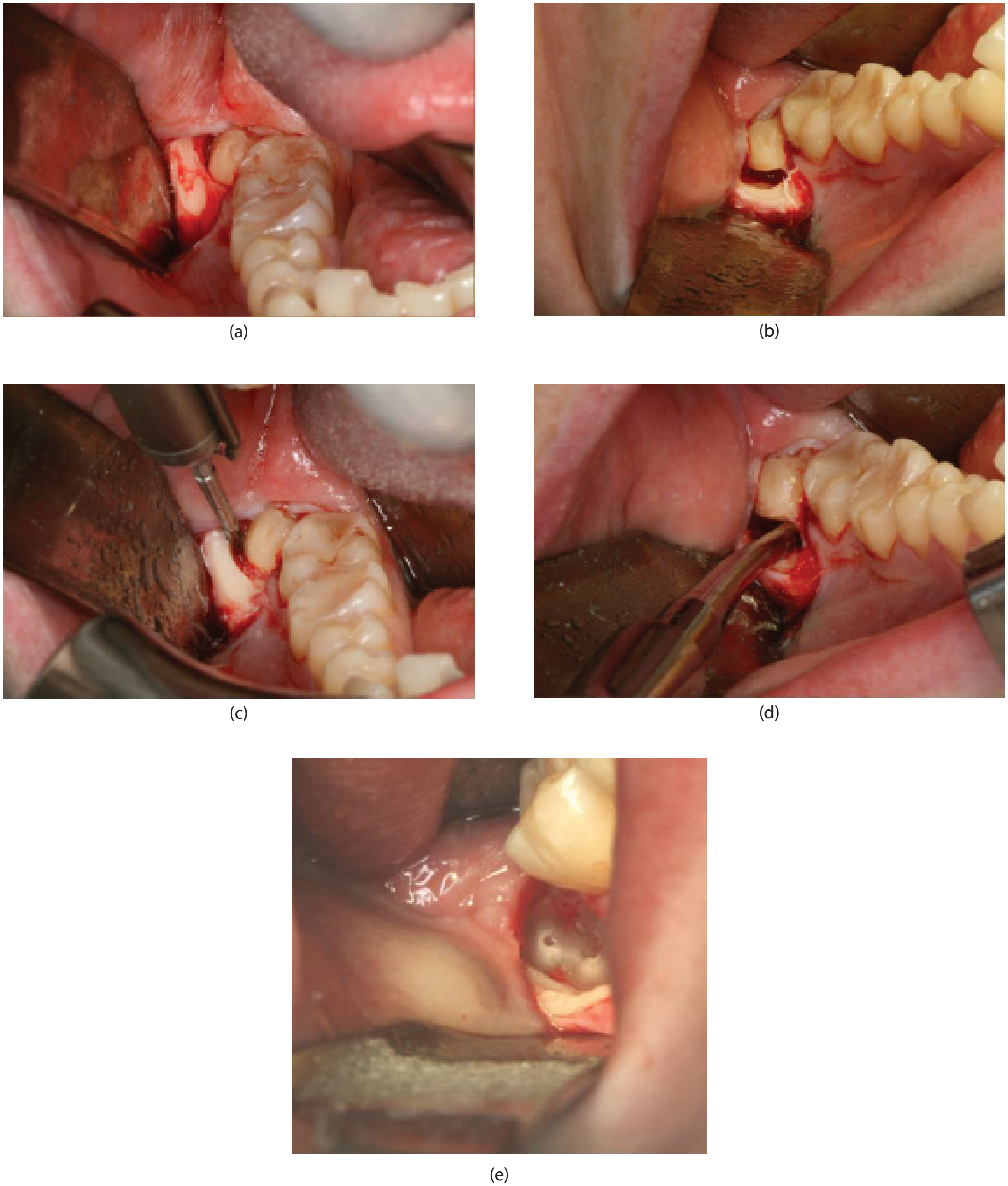


Figure 6.18 (a) Retraction of a triangular mucoperiosteal flap to expose an unerupted right M3M. (b) Bone removal to expose the cement–enamel (CEJ) junction. (c) Decoronation cut is made at the level of the CEJ and perpendicular to the long axis of the tooth. (d) Decoronation is completed with the insertion and rotation of an elevator. (e) Finished root surface which has been reduced 2–3mm below surrounding bone level complete with removal of coronal pulp remnants.

coronal pulp removed using a rose head bur. Care must be taken (especially with distoangularly impacted M3M) not to damage the adjacent root. Any roots which are noted to have become mobile during the coronectomy procedure should be removed using the sectioning technique, which is previously discussed. Primary wound closure is required.

Maxillary third molars

Surgical removal – Unerupted maxillary third molar

Surgical removal of unerupted maxillary third molars is indicated when there is infection, resorption or an associated cyst or tumour. Pre-operative assessment should include the identification of the proximity of the tooth to the maxillary

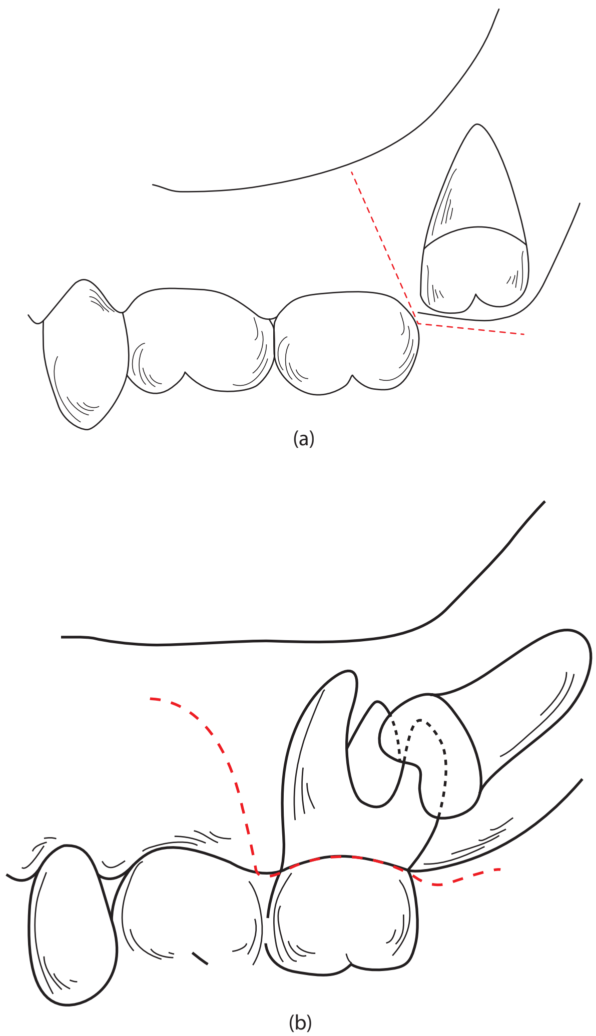


Figure 6.19 Flap design for the surgical removal of an unerupted maxillary third molar which is located: (a) In the tuberosity region, (b) More anteriorly.

sinus and adjacent second molar. Access to the unerupted tooth is achieved using a buccal approach with flap design being influenced by the position of the tooth. A full thickness triangular flap may be sufficient in cases where the tooth lies in the tuberosity region; however, if the tooth is more anteriorly placed then a two-sided flap with mesial relief anterior to the second molar provides better access (Figure 6.19).

Careful placement of a Howarth, Laster or Minnesota retractor during the surgical removal of unerupted maxillary third molars is important to prevent displacement of the tooth into the infratemporal fossa. The crowns of unerupted maxillary third molars are often buccally positioned and minimal, if any, bone removal is usually required to facilitate effective elevation. Where an impacted maxillary third molar is palatally inclined decoronation followed by sectioning of the root mass may be necessary. Prior to closure, the socket should be assessed for communication with the maxillary antrum as this would influence the post-operative regimen.

POST-EXTRACTION MANAGEMENT

Following the surgical removal of an unerupted tooth, the extraction site must be thoroughly debrided and particularly when the tooth has been surgically divided, inspected carefully to ensure that no tooth fragments remain. If closely related to the extracted tooth, the adjacent teeth should be examined for signs of iatrogenic damage or excessive mobility which if identified should be addressed. After irrigation beneath the flap retractor where bone and tooth debris tends to accumulate, the soft-tissue flap should be closed and ensuring that the gingival tissue of adjacent teeth is replaced in its pre-extraction anatomical position to minimize recession. Verbal and written aftercare instructions should be given and appropriate analgesics is prescribed.

Top tips

- Careful clinical and radiographic assessment of the position and the relationships of an unerupted tooth to adjacent structures optimizes the planning of its removal.
- Wherever possible, the removal of an unerupted tooth should be facilitated by sectioning of the tooth rather than bone removal.
- By ensuring that the cuts made to section a tooth remain within the tooth being extracted, damage to adjacent teeth may be minimized.
- Adequate access to and the visibility of an unerupted tooth during its removal are very important and should be clinically assessed pre-operatively. It should be recognized that any degree of limited opening or inelasticity of peri-oral tissues will complicate an extraction.

SUGGESTED READINGS

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7

Nerve injuries and repair

JOHN ZUNIGA and ANDREW BG TAY

CONTENTS

PRINCIPLES AND JUSTIFICATION

Trigeminal nerve injuries may occur from third molar surgery, local anaesthetic injections, orthognathic surgery, maxillofacial trauma, implant surgery or pathology surgery, and most often involve the inferior alveolar nerve, the lingual nerve (LN) and the infraorbital nerve. Nerve repair is indicated where the nerve injury is significant (Sunderland IV or V degree injury), demonstrated either by direct visual inspection or by clinical neurosensory testing or adjunctive testing (i.e. magnetic resonance neurography, trigeminal nerve conduction and chemosensory testing). Repair should be carried out at the earliest opportunity under microscopic magnification by a trained microsurgeon. (Although no standard exists for training in microneurosurgery of the trigeminal nerve, suggested standards for training in microsurgery exist and include a minimum 40+ hours of didactic courses and laboratory experience including the successful anastomoses of 10 arteries, 10 veins and 10 neural repairs. A trained microneurosurgeon should serve as first assistant to an experienced microneurosurgeon in at least three cases and then serve as primary surgeon in six cases.)

INDICATIONS

- Witnessed nerve injury from third molar surgery, orthognathic surgery (e.g. sagittal split osteotomy), implant surgery or mandibular or maxillary trauma
- Non-witnessed nerve injury with persistent severe or complete sensory impairment for approximately 3–6 months from third molar surgery, orthognathic surgery (e.g. sagittal split osteotomy), implant surgery or mandibular or maxillary trauma
- Chemical nerve injury (e.g. endodontic irrigation accident)
- Neuropathic pain

ANAESTHESIA

The operation is performed under general anaesthesia with nasoendotracheal intubation. The throat is packed with moist ribbon gauze and the endotracheal tube secured. Microneurosurgery is difficult to perform under local anaesthesia owing to movements of the awake patient being magnified under the microscope, and requires a longer operating time than can be afforded by deep sedation.

OPERATION

Position of patient

The patient is laid supine on the operating table and turned to keep the anaesthetic machine at about the waist level of the patient. The patient should be positioned in a way to allow two surgeons to sit on either side of the patient's head with an operating microscope over the patient's head.

The microsurgeons must be seated comfortably during the microsurgical phase of the procedure. Therefore, if the motor base of the operating table does not rotate free from the table, the patient should be positioned with the head at the foot end of the operating table. This affords the microsurgeons freedom to sit with their legs under the operating table. The face around the mouth and the oral cavity is cleansed. A head drape is used. If a nerve graft site has been identified prior to surgery, the selected location is prepared and draped for access. An operating microscope with two operator eyepieces should be available; the microscope focal distance is set at 250 mm with the zoom at mid-range. The operator eyepieces should be adjusted to suit the surgeons and draped. If available, video camera feed from the operating microscope is useful for recording and allowing other team members to see the procedure. Microsurgery in the oral cavity requires longer microsurgical instruments, usually around 18 cm length and preferably of the bayonet design. Bipolar diathermy and two separate suction tubings should be available.

For LN surgery, the operating surgeon sits on the same side of the operation site. For inferior alveolar nerve or infraorbital nerve surgery, the surgeon sits on the opposite side of the operation. Local anaesthetic with epinephrine (adrenaline) is given as an inferior alveolar nerve block and infiltrated around the operative site.

LINGUAL NERVE REPAIR

Access

The patient's head is kept central and a modified Dingman mouthgag is inserted to position the mouth open, using the tongue blade to keep the tongue from the operative site. Penny towels are used to prop up the Dingman handle (Figure 7.1). The modified Dingman should not be left in this position but removed, if there is a need to move away from the oral cavity for a time (e.g. to harvest a sural nerve graft) so as to avoid prolonged pressure and ulceration of the oral tissues.

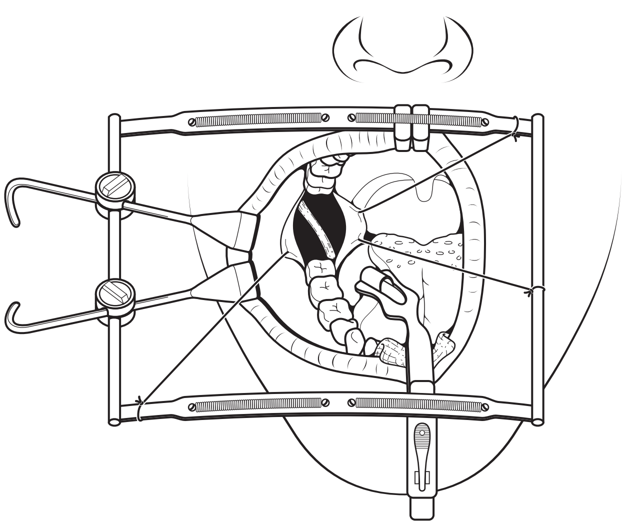

Figure 7.1 Modified Dingman retractor for lingual nerve (LN) microsurgical repair access.

An intra-oral mucosal incision is made with a No. 15 Bard-Parker (B-P) scalpel over the ascending ramus to the distal of the mandibular second molar. A buccal extension is made from the distal of the molar to the buccal sulcus, and a lingual extension is made to the lingual sulcus curving forward up to the mandibular first molar (Figure 7.2). The buccal and lingual mucosal flaps are raised supraperiosteally using a periosteal elevator and Metzenbaum curved dissecting scissors, and secured to the modified Dingman frame with 3/0 or 4/0 black silk sutures (Figure 7.3). Suction of the operative site is provided using a fine Frazier suction.

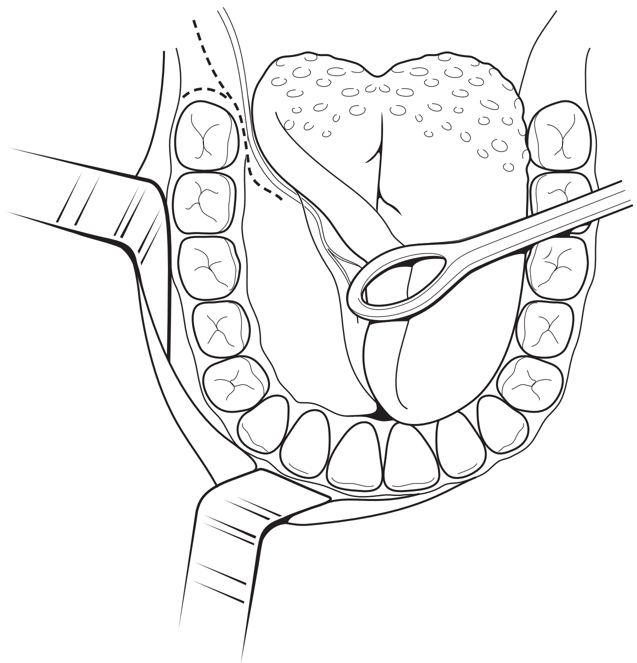

Figure 7.2 Supraperiosteal incision to access the LN.

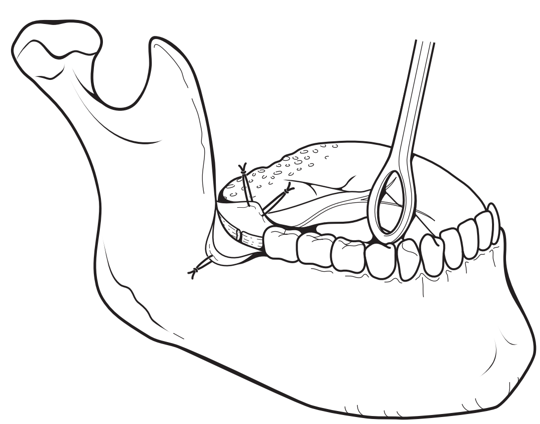

Figure 7.3 Supraperiosteal flaps are reflected and secured to the Dingman retractor for access to the LN.

Preparation

The operating microscope is brought into the operative field and positioned. The LN is located and exposed beginning at healthy nerve proximal and distal to the injury site; the LN is often found in a pouch of fat. The exposed proximal and distal nerve segments are carefully retracted with vessel loops, one proximal and one distal to the injury site (Figure 7.4). The injury site is often adherent to the lingual aspect of the mandible, and is released with careful microdissection using curved microscissors.

A modified background is placed beneath the released nerve. The background is made by sharply cutting the luerlock end of the small gauge butterfly venipuncture system and then advancing this cut end through a tunnel created in a 1- × 1-inch neuropatty and then securing the tubing within the neuropatty with silk suture. The neuropatty is then placed beneath the nerve at the injury site, and the needle end of the modified butterfly venipuncture system is inserted into the lumen of an active suction tubing. The nerve is examined under microscopic magnification (25×). The injury may be a complete transection with a neuroma at the end of each nerve segment, or a partial transection with a neuroma in continuity. The neuroma is carefully excised with straight microscissors and the nerve ends trimmed to expose the fascicular surfaces with periodic irrigation with heparin saline (Figure 7.5). A 6/0 or 7/0 monofilament suture is passed into the epineurium of each segment to the adjacent muscle and used to approximate the nerve segments together to facilitate repair without undue tension. If the nerve segments cannot be coapted without tension (approximately 1 cm or more of nerve gap), a nerve graft will be necessary.

Microsuture

The trimmed nerve endings are coapted, using the vasa nervorum as a guide aligning the nerve segments. Using an 8/0 or 9/0 monofilament on a cutting needle, the first suture is placed at the 12 o'clock position; a longer strand is left. Further sutures are placed in similar manner at the 4 and 8 o'clock positions (Figure 7.6).

The nerve may be 'flipped over' holding the suture strands with microforceps. The intervening gaps in the coaptation site are closed with circumferential sutures placed at regular intervals around the nerve; usually six to eight sutures may be required.

The repaired nerve is examined and any excess suture is trimmed. The approximating suture and then the background are carefully removed.

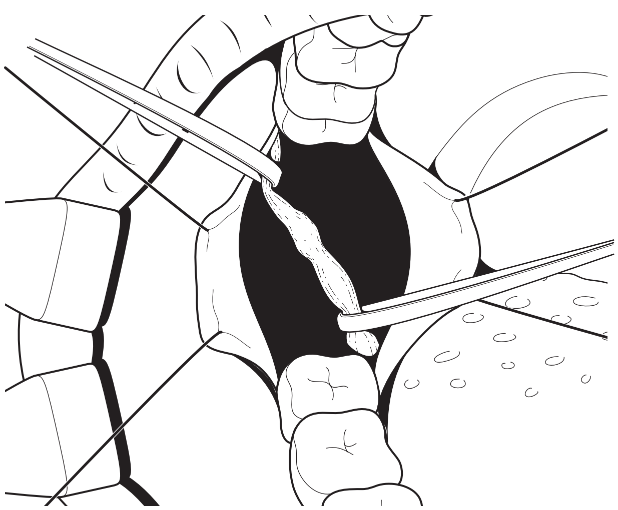

Figure 7.4 Retraction of proximal and distal LN with vessel loops to access LN injury site.

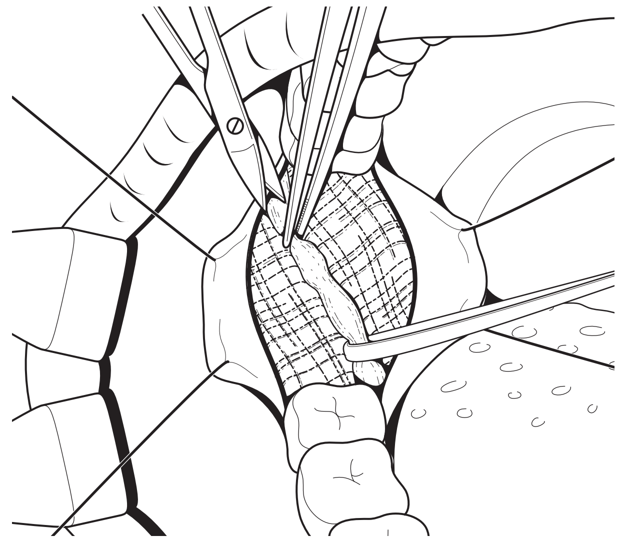

Figure 7.5 LN on modified background in preparation for repair.

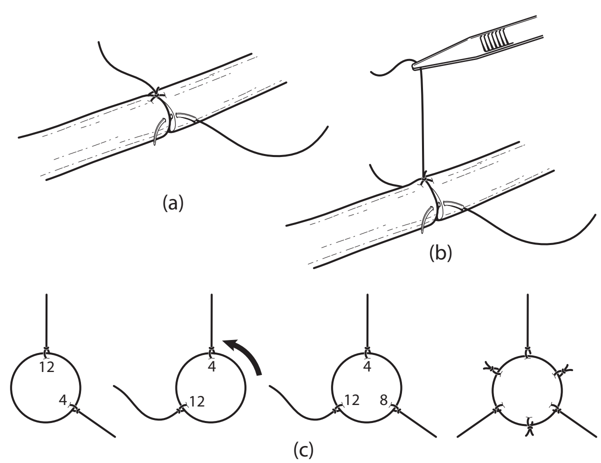

Figure 7.6 Microsuture sequence of neurorrhaphy. (a) The first suture is placed at the 12 o'clock position, followed by the second suture at the 4 o'clock position. These sutures are left long to provide a holding point. (b) The nerve is rotated to expose the underside surface, where the third suture is placed at the 8 o'clock position. (c, right) The nerve repair is completed by placing other sutures in between the first three sutures.

Wound closure

The microscope is moved out of the operative field. The black silk sutures retracting the buccal and lingual mucosal flaps are released and removed. The operative site is irrigated with saline. The mucosal flaps are replaced and closed with 4/0 Vicryl interrupted sutures.

The modified Dingman mouth gag and then the throat pack are removed. The patient is reversed and extubated by the anaesthetist.

INFERIOR ALVEOLAR NERVE REPAIR

Access

The patient's head may be turned to the side opposite the operation site. An incision is made just above the mandibular buccal sulcus from the midline of the lower lip posteriorly to the ascending ramus, using a No. 15 B-P scalpel. A sub-periosteal flap is raised exposing the mandible from the alveolus to the inferior border, including the mental foramen, taking care to preserve the mental nerve.

A small round bur is used to create grooves radiating outwards from the mental foramen, then joined to form windows in the buccal cortical bone. The bone windows are carefully fractured with either a Coupland or Warwick–James elevator, taking care to avoid the mental nerve. Windows are created in a similar manner over the course of the inferior alveolar nerve from anterior to posterior, bearing in mind the downward and backward turn made by the nerve before it exits the mental foramen (Figure 7.7). The inferior alveolar nerve is exposed to 1 cm beyond the site of injury; the incisive branch is sharply divided with a scalpel and the inferior alveolar nerve is carefully dissected free from its bed (Figure 7.8).

Preparation

The operating microscope is brought into the operative field and positioned. The proximal and distal nerve segments are lifted from the mandibular bone with a nerve hook, and

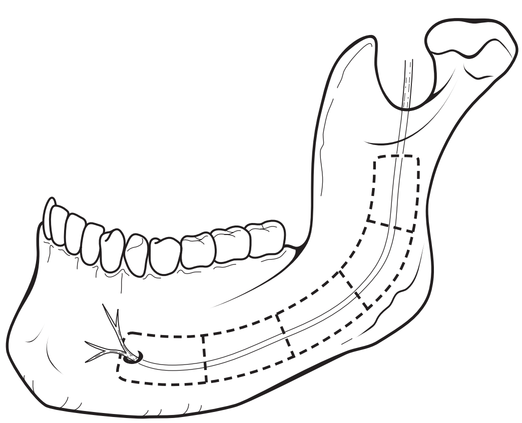

Figure 7.7 Lateral decortication to expose the inferior alveolar nerve.

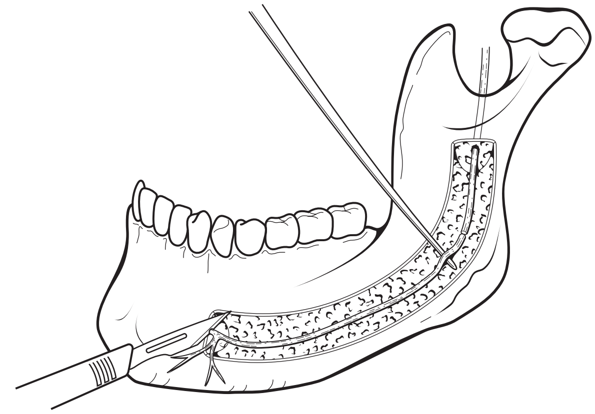

Figure 7.8 Incisive nerve division with a scalpel, lateralization of the inferior alveolar nerve and preparation of the nerve injury (nerve hook).

a modified neuropatty background is placed beneath the nerve segments. The nerve is examined under microscopic magnification. The injury may be a complete transection or a partial transection with a neuroma in continuity.

The neuroma is carefully excised with straight microscissors and the nerve ends trimmed to expose the fascicular surfaces with periodic irrigation with heparinsaline. If necessary, a 6/0 or 7/0 monofilament suture passed through the epineurium of each segment and used to approximate the nerve segments together to facilitate repair without undue tension. As the distal nerve is transposed towards the proximal, a nerve graft will usually not be necessary.

Microsuture

The trimmed nerve endings are coapted, using the vasa nervorum as a guide aligning the nerve segments. Using an 8/0 or 9/0 monofilament on a cutting needle, the first suture is placed at the 12, 4 and 8 o'clock positions; a longer strand is left at each suture to facilitate further placement of sutures (Figure 7.6). The intervening gaps in the coaptation site are closed with circumferential sutures placed at regular intervals around the nerve; usually six to eight sutures may be required. The result is repositioning of the distal nerve segment so that the mental nerve is positioned posteriorly to the original foramen to avoid a nerve graft (Figure 7.9).

The repaired nerve is examined and any excess suture is trimmed. The approximating suture and then the background are carefully removed. Gelfoam is sometimes placed around the nerve and the nerve is replaced in its bed.

Wound closure

The microscope is moved out of the operative field. The operative site is irrigated with saline. The mucosal flap is replaced and closed with 4/0 Vicryl interrupted sutures.

The throat pack is removed and the patient is reversed and extubated by the anaesthetist.

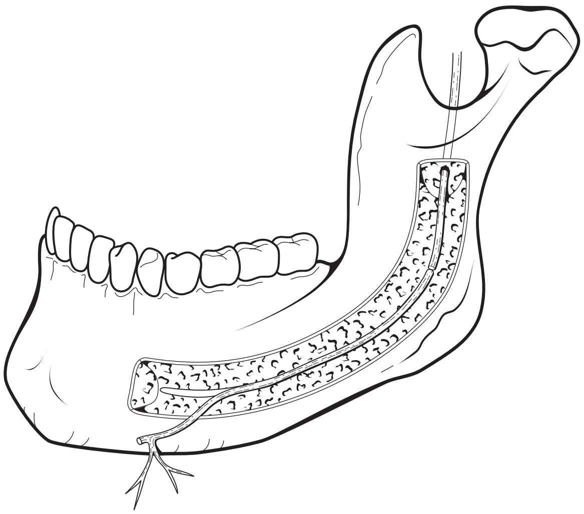

Figure 7.9 Transposition of the mental nerve posteriorly for completion of the inferior alveolar nerve repair.

INFRAORBITAL NERVE REPAIR

Access

Two approaches are used for microneurosurgical repair of the infraorbital nerve. A cutaneous approach is used when the site of injury is proximal to the infraorbital foramen. An intra-oral approach is used when the site of the injury is close to or distal to the infraorbital foramen.

1. The globe is protected with a temporary tarsorrhaphy using 4/0 silk suture or a scleral shell. The subciliary incision line is drawn with a skin marker approximately 2 mm inferior to the eyelashes along the length of the lower eyelid. The incision may be extended laterally to 2 cm beyond the lateral canthus, curving inferiolaterally following a natural skin crease. The incision line is infiltrated with local anaesthetic with epinephrine. The subciliary incision is made with a No. 15 B-P scalpel to the subcutaneous layer, until the underlying orbicularis oculi muscle is visible. Sharp curved scissors are used for subcutaneous dissection for a few millimetres inferiorly towards the inferior orbital rim. Scissors are used to dissect through the orbicularis oculi muscle to the periosteum overlying the inferior orbital rim, reaching the plane between the muscle and septum orbitale. The skin–muscle flap of tissue is elevated from the lower eyelid and retracted inferiorly. The periosteum over the inferior orbital rim is incised with a No. 15 B-P scalpel a few millimetres below the edge of the rim. The periosteum is elevated with a periosteal elevator until the infraorbital foramen is reached, usually located 7–9 mm inferior to the inferior orbital rim.
2. An intra-oral vestibular incision is made in the unattached mucosa of the maxillary vertibule from the midline to the zygomatic process. The nerve is exposed via a sub-periosteal dissection. The infraorbital nerve immediately branches into up to 10 branches at the foramen.

A small round bur is used to create a groove around the infraorbital foramen. The bone around the foramen is carefully removed with Rongeur forceps. The infraorbital canal is carefully unroofed exposing the infraorbital nerve until 1 cm beyond the injury site, and may reach the orbital floor (Figure 7.10).

Preparation

The operating microscope is brought into the operative field and positioned. The proximal and distal nerve segments are lifted from the bone with a nerve hook, and a modified neuropatty background is placed beneath the nerve segments. The nerve is examined under microscopic magnification. The injury may be a complete transection or a partial transection with a neuroma in continuity.

The neuroma is carefully excised with straight microscissors and the nerve ends trimmed to expose the fascicular surfaces with periodic irrigation with heparinsaline. An approximating suture using 6/0 or 7/0 monofilament is passed through the epineurium of each segment and used to approximate the nerve segments together to facilitate repair without undue tension.

Microsuture

The trimmed nerve endings are coapted, using the vasa nervorum as a guide aligning the nerve segments. Using an 8/0 or 9/0 monofilament on a cutting needle, sutures are placed at the 12, 4 and 8 o'clock positions (Figure 7.6). Circumferential sutures are placed at regular intervals around the nerve; usually six to eight sutures may be required.

The repaired nerve is examined and any excess suture is trimmed. The approximating suture and then the background are carefully removed (Figure 7.11).

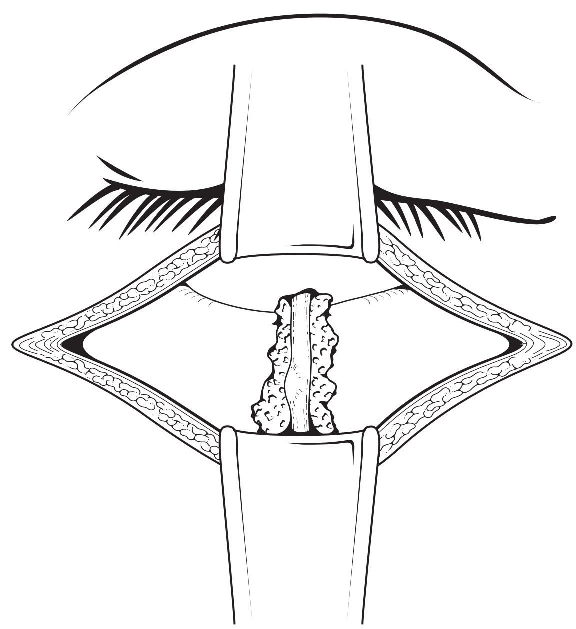

Figure 7.10 Transcutaneous approach to access injury of the infraorbital nerve.

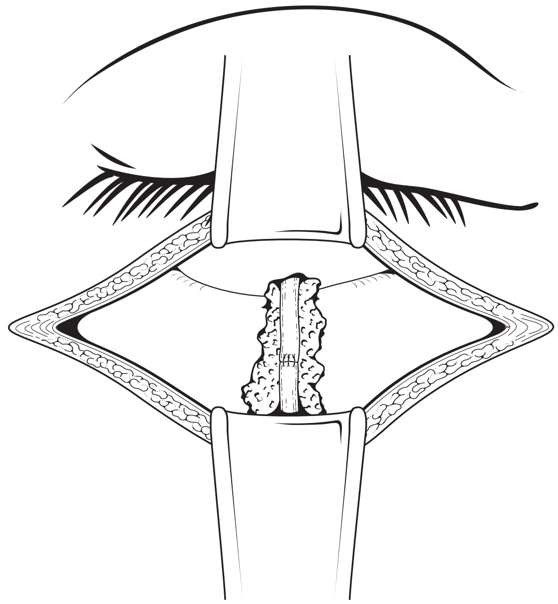

Figure 7.11 Infraorbital nerve microsuture repair *in situ*.

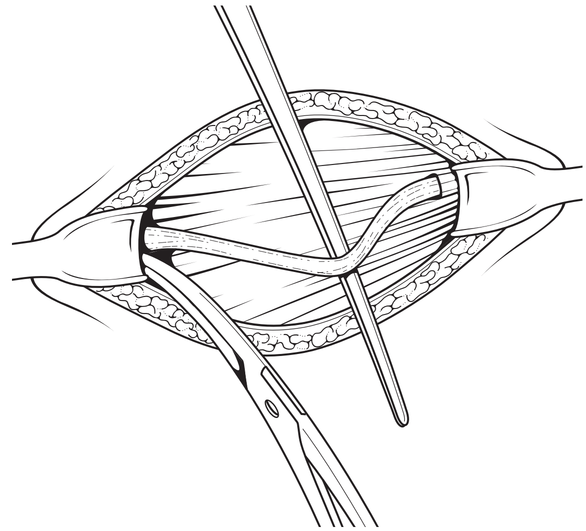

Figure 7.12 Sural nerve is lateralized.

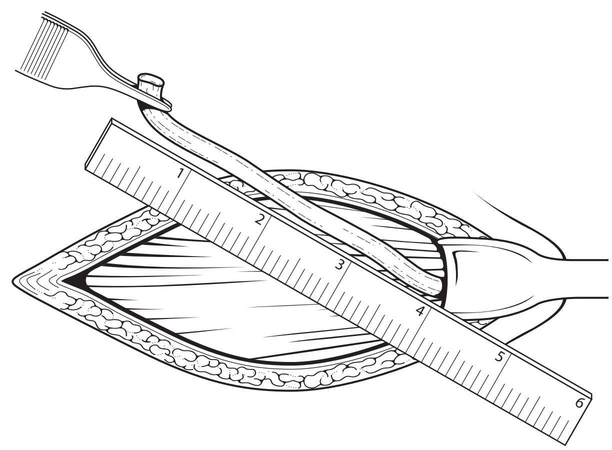

Figure 7.13 Sural nerve is exteriorized to determine its length.

Gelfoam may be placed around the nerve and the nerve is replaced in its bed.

Wound closure

The microscope is moved out of the operative field. The operative site is irrigated with saline. The periosteum is closed with 4/0 silk sutures, and the skin–muscle flap is replaced and closed with 4/0 silk interrupted sutures or a running 6/0 non-resorbable suture. The patient is reversed and extubated by the anaesthetist.

SURAL NERVE GRAFT

The sural nerve remains the 'workhorse' of autogenous nerve graft applications in trigeminal nerve repair. Alternative autogenous nerve graft locations are the greater auricular and medial antebrachial cutaneous nerves. The sural nerve is easily harvested by a 2-cm curvilinear incision one finger breadth distal and superior to the lateral malleolus of the ankle. The sural nerve, the small saphenous vein and artery are within the subcutaneous tissues of the lateral leg and are superior to the fascia of the posterior tibialis muscle. The nerve is isolated from the vein and artery using vessel loops and dissected as far distally and proximally as possible (Figure 7.12). The most distal end is transected sharply and the sural nerve exteriorized to determine the length required for adequate grafting of the lingual or inferior alveolar nerve (Figure 7.13). If greater length is required, a second incision above and parallel to the first is made until the adequate length of nerve is obtained. At least 1 cm of proximal nerve is spared so that after harvesting, the proximal stump can be repositioned into the muscle to avoid painful neuroma formation. This is accomplished by creating a small 'trap door' access through the posterior tibialis fascia to expose the muscle and then suturing the proximal stump of the sural nerve against muscle using resorbable suture, closing the fascia over the stump and completing the skin closure (Figure 7.14). The wound is then dressed and supported with an elastic gauze bandage (Ace bandage). Non-weight bearing crutches are provided. The patient is instructed to change the bandage daily to avoid compression for 1 week. Non-weight bearing activity is enforced for 2 weeks after which sutures are removed.

Post-operative care

A gauze pack may be placed over the operative site intra-orally. The patient is transferred to the post-operative anaesthesia care unit and may either be allowed home or admitted

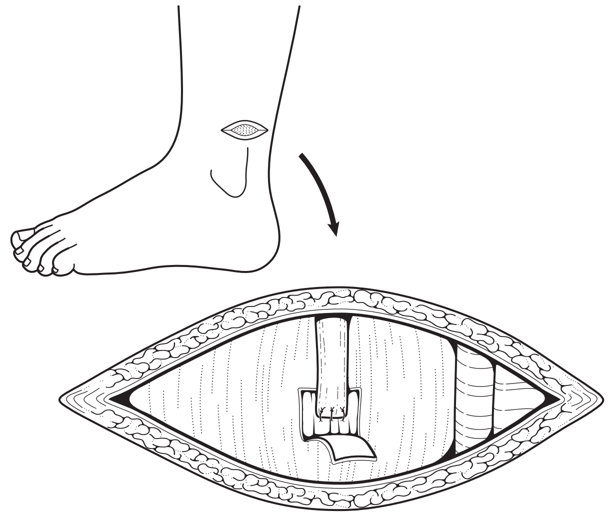

Figure 7.14 Sural nerve stump connected to muscle under fascial trapdoor.

to the ward overnight. Analgesia and chlorhexidine mouth rinse is prescribed; post-operative wound care instructions are provided. Adjunctive medication for neuropathic pain should be continued if these have been in use preoperatively. The patient is followed up 7–10 days later and may be given instructions for sensory retraining which can begin immediately and continued for up to 1 year after surgery. Mandibular range of motion should be normal by 1 month. Clinical neurosensory testing can begin 3 months after surgery since the first statistical indicator of regeneration occurs no sooner than 6–8 weeks post-operatively in half the patients. Sensory regeneration should be complete by 1 year in the majority of patients so that discharge should occur after the 1-year follow-up time. Exceptions to this rule occur due to age, location of injury and degree of injury. Older patients, more distal injuries (mental nerve versus inferior alveolar nerve), complete transection injuries requiring nerve grafts are expected to reach maximum regeneration over longer times (beyond 1 year).

Complications

- Intra-operative bleeding
- Infection
- Pathologic fracture of the mandible
- Wound dehiscence
- Trismus
- Inability to locate one nerve segment
- Neuropathic pain
- Neuroma formation in nerve graft donor site.

Top tips

- Position the patient appropriately before commencing surgery so that the microsurgeons are comfortable throughout the procedure.
- Demagnetize the microsurgical instruments before surgery.
- Use an operating microscope that has two viewing ports and a video feed.
- Use a neuropatty with suction via a butterfly cannula as background.
- Irrigate the nerve repair site with heparin saline during neurorrhaphy.

SUGGESTED READINGS

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8

Surgical endodontics

HELEN SPENCER

CONTENTS

INTRODUCTION

Surgical endodontics aims to treat microbial infection of the root canal and peri-radicular tissues which persist following conventional orthograde treatment. Surgical procedures include apicectomy (root-end resection) usually in association with retrograde root filling, lateral perforation repair, root resection and hemisection. Root resection and hemisection will not be considered in detail, but the surgical principles are broadly similar. The most frequently performed procedure is apicectomy with retrograde root filling usually following unsuccessful orthograde treatment.

It must be remembered that reroot treatment is the gold standard treatment in most cases and surgery should be considered only when more conservative treatment is not possible or appropriate (Table 8.1).

Presurgical assessment must ensure that retention of a surgically treated tooth is appropriate to the long-term dental health of the patient. The teeth listed for surgery should be restored with a successful coronal seal. Any extracoronal restorations should not have a history of cementation failure. The vitality of adjacent non-endodontically treated teeth and mobility and periodontal pocketing of teeth in the surgical area may influence the outcome of surgery. Peri-apical radiographs must be available for teeth involved in surgery; they should be taken using a paralleling technique to enable root-length determination. Panoral films may be necessary to demonstrate the extent of larger lesions. The advent of CBCT imaging has made more specific diagnosis possible.

The microbial invasion of most peri-radicular lesions can alter the clinical picture in a short time and these signs should be reassessed just prior to surgery.

SUCCESS RATES

Success rates have been shown to increase with recent advances in technique, including root-end resection without a bevel, the use of ultrasonics for root-end cavity preparation and the move away from amalgam as the restorative material of choice. Previously, success rates of between 50% and 80% were quoted, with highest success rates for upper anterior teeth. Full radiographic healing is now being reported in more than 90% of cases, with most studies suggesting over 80% with full healing at one year. This improvement in initial outcome is likely to reduce the need for repeat surgery.

Unsuccessful apical surgery will reduce the volume of bone available for osseointegration. Repeat surgery may compromise or complicate future implant placement in the area.

Table 8.1 Indications and contraindications for surgery.

Indications/Contraindications	
Indications	Failed conventional orthograde treatment where repeat treatment is either not possible, appropriate or unsuccessful
	Canals unable to be instrumented fully by orthograde approach, for developmental or iatrogenic reasons
	Biopsy of peri-radicular lesion required
	Visualization of the root surface required (suspected root fracture)
	Root sectioning or amputation required
Contraindications	Anatomical, including root morphology, proximity to neurovascular bundle, access
	Subsequent successful and suitably aesthetic restoration not possible
	Periodontally compromised
	Unsuccessful surgery would compromise subsequent replacement
	Patient factors, including medical and social

PRE-OPERATIVELY

Provide chlorhexidene 0.2% mouthwash to reduce the oral bacterial load. A pre-operative dose of non-steroidal analgesics can be provided for suitable patients. Some clinicians commence this regime 24 hours prior to surgery.

Magnification must be used, ideally a microscope, to improve visualization of the lesion and root apex.

ANAESTHESIA

Whilst extensive lesions may require general anaesthesia, the majority of patients will be treated under local anaesthesia leaving the surgery following a short recovery period. Regional local anaesthetic blocks, where possible, are to be recommended. The vasoconstriction provided by local infiltration in addition to either a regional block or general anaesthesia is advised for all patients.

FLAP DESIGN

All the flaps described should be full thickness mucoperiosteal, with the incision perpendicular to the mucosal surface in all areas other than the gingival sulcus where the scalpel is placed within the gingival crevice incising from the base of the pocket to the crest of the alveolar bone. Relieving incisions should not cross an eminence or divide a fraenal attachment as this will increase tension on the replaced flap (Figure 8.1).

The need to avoid the mental foramen and nerve will influence the position of any relieving incision in the lower premolar and first molar region.

Flaps involving the gingival margin

Post-operative gingival recession is most relevant in the anterior region. An alteration to the emergence profile, especially in the presence of crown or bridge margins, may lead to failure of the apicectomy for aesthetic reasons.

For this reason, flaps which do not involve the gingival margin or gingival papilla are increasingly utilized.

Flaps not involving the gingival margin

These include Luebke–Oschenbein (Figure 8.1), horizontal, vertical, semilunar and flaps utilizing microsurgical techniques, such as the papilla base incision.

Papilla base incisions and other microsurgical techniques are described in the recommended texts.

The Luebke–Oschenbein removes the risk of post-operative gingival recession, provides adequate access to the apex of the tooth and is easily repositioned. The horizontal incision lies within the attached mucosa and follows the scalloped contour of the gingival margin. The literature suggests a minimum of 2 mm of attached mucosa coronally to the horizontal incision to minimize the risk of papillary necrosis, 4 mm is often more practical. Healing is compromised if periodontal bone loss extends apically or the lesion coronally beyond the horizontal incision. Placement of the vertical incision is as for gingival margin flaps. This flap was described as three sided, but may not require the second relieving incision. When treating a purely apical lesion and there is adequate height of unattached mucosa overlying the apex of the tooth, a similar flap may be raised wholly within the unattached mucosa. The slight increase in bleeding is minimized by infiltrating a vasoconstrictor containing local anaesthetic pre-operatively (Table 8.2).

Other flaps not involving the gingival margin

Single horizontal and vertical incisions have been used. The absence of a relieving incision reduces access. Advances in imaging demonstrate that very few lesions are appropriate for this approach. The semilunar flap has the disadvantages

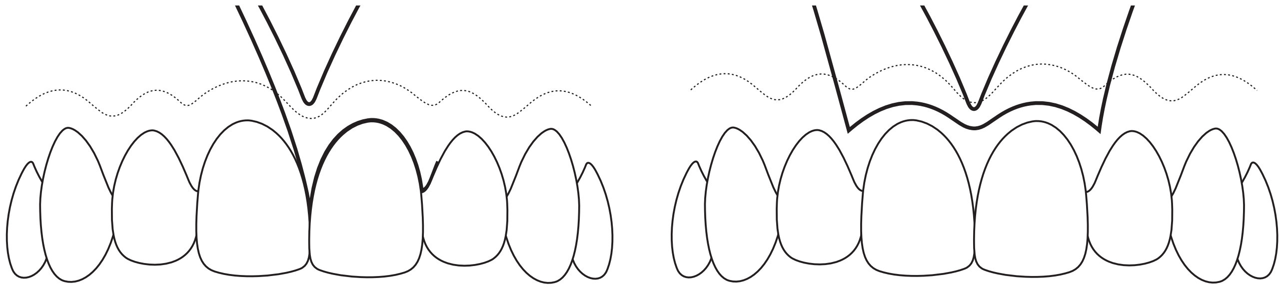

Figure 8.1 Two-sided or triangular flap. No distal relieving incision. Provides adequate access posteriorly and often sufficient anteriorly, especially if access to the apex is not required, e.g. lateral perforation repair. Can be extended to three-sided if greater access is found to be necessary. Again the fraenum or eminence should not be crossed with a relieving incision. Luebke–Oschenbein flap.

Table 8.2 Advantages and disadvantages of gingival margin flaps.

Advantages/Disadvantages	
Advantages	Excellent access, enabling visualization of full length of root/overlying bone Advantageous where lesion does not originate apically, or extends coronally beyond the area exposed by other designs of flap Good access for perforation repair, root resection and hemisection Horizontal element does not divide labial vessels, possibly improving visibility and reducing post-operative swelling Straightforward, uses technique routine in dentoalveolar surgery
Disadvantages	Gingival recession occurs post-operatively

of flaps without relieving incisions and its curvature can make retraction difficult and closure unpredictable. These single incision flaps are not to be recommended.

PROCEDURE

Flaps are raised with fine periosteal elevators. In areas where the soft tissue of the lesion has fenestrated the bone, careful dissection is necessary to elevate the overlying mucosal flap without perforation. Tissues should be retracted with an instrument such as a Cawood Minnesota retractor. This non-toothed retractor is wide enough to provide access and protect the labial soft tissues. If a lengthy procedure is expected, ensure that the flap does not desiccate. The author achieves this by placing saline-soaked gauze between the flap and retractor.

If there is no bone fenestration, the apex of the tooth is exposed by removal of bone using an irrigated round bur. The starting point may be identified by probing the bone surface with a sharp instrument to identify an area of thinning, and by estimating the length and alignment of the tooth from the pre-operative peri-apical radiograph. The true long axis may be disguised in a crowned tooth. From the initial point of entry, the bone window is increased to give sufficient access to perform the root-end resection and curette the soft tissue from the entirety of the defect. The position of the inferior alveolar canal and its upward curve to the mental foramen should be kept in mind during bone removal for apical surgery involving lower molar and premolar teeth.

Crypt control

The granulation tissue is removed using curettes, dental excavators and gauze pellets. Gauze pellets may also be useful in removing the lesion from palatal mucosa where bony fenestration has occurred. It is not possible to determine clinically whether granulation tissue present is part of the destructive or reparative process, and it may be appropriate to retain tenacious granulation tissue rather than instrument the root surface of an adjacent tooth. The soft tissue removed should be preserved for histological evaluation.

Some clinicians advocate the use of ribbon gauze with or without a vasoconstrictor placed within the bony defect prior to placement of the retrograde filling to aid haemostasis, better visualize the root end and facilitate removal of excess filling material from the cavity.

Root-end resection

The apex of the tooth is resected, perpendicular to the long axis of the tooth to minimize the number of exposed dentinal tubules. Dentinal tubules allow communication between untreated contaminated areas of the root canal system and the peri-apical tissues. The level of the resection should be sufficient to remove the portion of the root canal system identified pre-operatively as potentially harbouring micro-organisms, usually 3–4 mm. It is not necessary to resect the root at the base of the cavity as

this will expose a larger dentinal surface and reduce the remaining root length for restoration and stability. The orthograde root filling will usually be exposed by the resection. If mineral trioxide aggregate (MTA) has been used for the orthograde filling, no root-end preparation is necessary (Figure 8.2).

The root-end cavity is prepared using contra-angled surgical ultrasonic tips (Figure 8.3). These are preferred over rotary instruments as correctly angled cavity preparation is easier and there is a reduced risk of fractures forming within the retained root tissue. The preparation must encompass the width of the root canal system and have a minimum depth of 3 mm for adequate restoration.

The retrograde filling material of choice is MTA and other options are modified zinc oxide eugenol cements (IRM, which includes polymethacrylate, Super EBA, which includes ethoxybenzoic acid). There is sufficient evidence to contraindicate the use of amalgam, which has the added disadvantage of tattooing adjacent soft tissues in some patients. Only MTA stimulates hard-tissue deposition in direct contact with the filling material.

The prepared cavity is dried with paper points and gauze pledgets or reduced pressure air spray. The MTA is mixed according to the manufacturers' instructions and placed into the prepared cavity using specially designed carriers, small pluggers and flat plastic instruments. Excess MTA is wiped away using damp cotton wool. The restoration should be adequately condensed and burnished for best results, debris removed and the flap repositioned and sutured. Some specialists advocate radiographic imaging before closure. When early review is possible, 5/0 synthetic monofilament sutures are preferred. If this is not possible, vicryl rapide is recommended. Single interrupted sutures are used; however, and where a gingival margin flap has been raised, suspensory sutures may improve the aesthetic result. Following suturing, pressure should be placed to the flap using a moistened gauze pack. This pressure should be maintained for 5 minutes. This improves the adaptation of the flap and haemostasis (Figures 8.4 and 8.5).

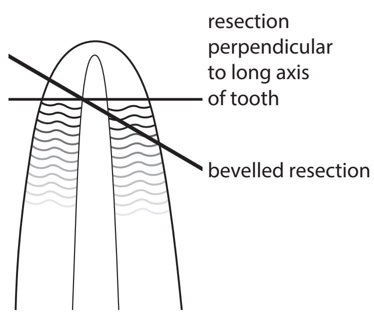

Figure 8.2 Root-end resection. Resection perpendicular to the long axis of the tooth.

Post-operatively

Antibiotics are not routinely prescribed; analgesia may be required for several post-operative days. When possible, the patient should be reviewed 3–4 days later to remove sutures and take a peri-apical radiograph of the apicected tooth. Subsequent reviews should note any pain or tenderness to percussion, buccal swelling or sinus, unexpected or increasing mobility, loss of vitality in adjacent teeth, presence of gingival recession.

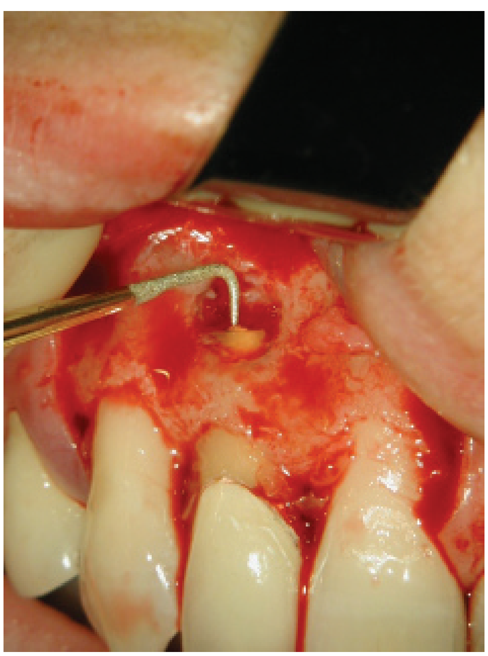

Figure 8.3 Root-end resection. Preparation with contra-angled ultrasonic tip.

Figure 8.4 Root-end resection. Prepared cavity.

Figure 8.5 Root-end resection. Mineral trioxide aggregate (MTA) *in situ*.

Radiographically, the procedure is said to be successful with bony infilling of the peri-radicular defect and appearance equivalent to that of a normal periodontal ligament and lamina dura. This imaging should be no less than 3 months post-operatively.

COMPLICATIONS

Once the flap is raised and the root is visualized, it may become apparent that the tooth is non-salvageable. Likely causes include root fracture, palatal perforation, lateral canal inaccessible to surgery or root resorption.

Late complications are commonly due to failure to eliminate the causative micro-organisms resulting in continuation of the inflammatory and infective processes.

The possibility of aesthetic failure will have been discussed pre-operatively, in some cases gingival creep will improve the appearance of small defects over a period of months, but results cannot be predicted.

Top tips

- Ensure tooth has adequate coronal seal and is restorable post-operatively.
- Ensure best possible orthograde root filling is provided prior to considering surgical treatment.
- Reassess periodontal pocket depths prior to surgery.
- Consider a flap avoiding full gingival margin flap where the soft tissues and the access it would provide allows.
- Use magnification.
- Prepare root-end cavity with ultrasonic instruments.
- Use mineral trioxide aggregate (MTA).
- Apply pressure for 5 minutes on completion of surgery.
- Remove sutures at 3–4 days.
- Do not compromise future implant placement.
- Avoid operating if there is a more appropriate conservative option.

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9

Cysts of the jaws, face and neck

ERIC R CARLSON

CONTENTS

KEY CONSIDERATIONS

1. A multilocular radiolucent lesion of the jaws ought to be incisionally biopsied in order to establish a microscopic diagnosis prior to rendering definitive treatment.
2. Despite controversies in nomenclature, the keratocystic odontogenic tumour (KOT) and the odontogenic keratocyst (OKC) are managed identically and independently of nomenclature.
3. Large, clinically diagnosed dentigerous cysts should be pathologically processed to rule out the presence of a unicystic ameloblastoma.
4. The glandular odontogenic cyst may microscopically resemble a central mucoepidermoid carcinoma such that a precise histopathologic diagnosis is paramount to proper surgical therapy.
5. A branchial cleft cyst may clinically resemble a lymphoma of the neck such that a thorough history and physical examination is required to preliminarily distinguish these processes. Most commonly, the computed tomography (CT) scans will provide the distinction as the branchial cleft cyst contains fluid while a lymph node containing cancer would be solid.

Cysts are common and clinically diverse lesions of the oral/head and neck region that must be considered when examining and creating a differential diagnosis of an expansile process of the jaws, face or neck. The characteristic clinical presentation, radiographic appearance and history of these lesions result in the formation of a focused differential diagnosis that leads to proper and expedient surgical treatment. Most of these cysts, in fact, may be surgically excised with curative intent without first performing an incisional biopsy. Under such circumstances, the pathologic diagnosis is definitively established following complete excision.

ODONTOGENIC CYSTS OF THE JAWS

With rare exceptions, epithelial-lined cysts in bone are seen only in the jaws.[1] Other than a few cysts that may result from the inclusion of epithelium along embryonic lines of fusion, most jaw cysts are lined by epithelium that is derived from odontogenic epithelium, hence the term *odontogenic cysts*.

Dentigerous cyst

Dentigerous cysts of the jaws develop in association with impacted teeth, most commonly mandibular third molars. Maxillary third molars, maxillary canines and mandibular second premolars are also observed to be associated with dentigerous cysts. They may also occur in association with supernumerary teeth and odontomas; however, they are only rarely associated with primary teeth.[1,2] Although dentigerous cysts occur over a wide age range, they are most commonly seen in patients between the ages of 10 and 30 years. Many dentigerous cysts are small asymptomatic lesions that are discovered serendipitously on routine radiographs, although some may enlarge to considerable size thereby causing bony expansion.

Radiographically, the dentigerous cyst represents the prototypical unilocular radiolucency, often with a sclerotic border (Figure 9.1). A large dentigerous cyst may give the impression of a multilocular process because of

Figure 9.1 A dentigerous cyst of the left mandible associated with impacted tooth no. 17. The cyst is noted to be a unilocular radiolucency and is exhibiting root resorption of tooth no.'s 18 and 19 with scalloping of the inter-radicular areas.

the presence of bony trabeculae within the radiolucency, but dentigerous cysts are grossly and histopathologically unilocular processes and probably are never truly multilocular lesions.[1]

One diagnostic and treatment dilemma for oral and maxillofacial surgeons involves the clinical and radiographic distinction between a dentigerous cyst and an enlarged dental follicle. This distinction becomes clinically significant when the surgeon considers whether to submit tissue removed with an impacted third molar for histopathologic examination as opposed to clinical designation as a follicle that may be discarded without microscopic analysis. The radiographic distinction becomes somewhat arbitrary; however, any pericoronal radiolucency that is larger than 4–5 mm is considered a cyst and should be submitted for microscopic examination. It is noteworthy that pathologists also struggle with the distinction between dental follicles associated with developing teeth and odontogenic lesions.[3,4] It seems that odontogenic cysts, odontogenic fibroma and odontogenic myxoma are the lesions most often incorrectly offered as diagnoses for follicles by surgical pathologists owing to a general unfamiliarity with the normal process of odontogenesis.[3] Of perhaps even greater concern in terms of proper diagnosis and treatment is the large unilocular radiolucency. Although most commonly classified radiographically as dentigerous cysts, it is incumbent upon the surgeon to section these excised specimens in the operating room and to consider frozen-section analysis. This exercise is important so as to rule out the existence of a unicystic ameloblastoma that would at least require an aggressive curettage with curative intent.

Most dentigerous cysts are treated with enucleation of the cyst and removal of the associated tooth, most commonly without a preceding incisional biopsy due to the unilocular nature and likely diagnosis of the lesion (Figure 9.2). The routine application of curettage of the cyst cavity is always advisable at the time of removal of the cyst in the event that a more aggressive cyst or an odontogenic tumour amenable to curettage is diagnosed

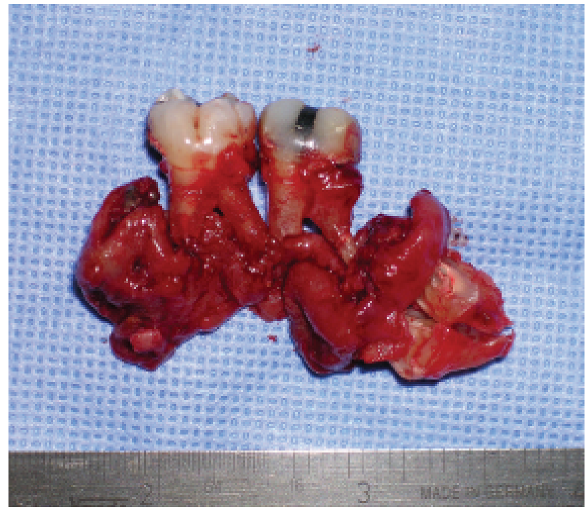


Figure 9.2 The specimen from the enucleation and curettage surgery for the dentigerous cyst seen in Figure 9.1. The removal of several associated teeth was performed for complete cyst removal.

histopathologically following removal in an office setting. Such diagnoses would include the OKC and the unicystic ameloblastoma.

Large dentigerous cysts may be treated with marsupialization when enucleation and curettage might otherwise result in neurosensory dysfunction or predispose the patient to an increased chance of pathologic fracture post-operatively. Some patients who are not candidates for general anaesthesia may also be treated with a marsupialization procedure in an office setting under local anaesthesia. This permits decompression of the large dentigerous cyst with a resultant reduction in the size of the cyst and bony defect. At a later date, the smaller cyst can be removed as part of a smaller scale surgery.

Histopathologic examination of all radiolucencies that are empirically diagnosed as dentigerous cysts is paramount in the treatment of these cysts. This includes those lesions that are enucleated as well as those that undergo marsupialization, during which procedure it is important to inspect the cyst lumen and submit a representative portion of the lesion for histopathologic examination. Support of this statement is derived from the occasional formation of a squamous cell carcinoma, mucoepidermoid carcinoma or ameloblastoma from or in association with a dentigerous cyst.[5–7] The prognosis for most histopathologically diagnosed dentigerous cysts is excellent, with recurrence being a rare occurrence.

Odontogenic keratocyst/keratocystic odontogenic tumour

The OKC is a distinct form of odontogenic cyst that deserves special consideration because of its controversial nomenclature and reported aggressive

clinical behaviour. Some investigators have proclaimed the OKC as a benign cystic neoplasm rather than a cyst, applying the nomenclature KOT of the World Health Organization in their most recent classification of odontogenic tumours in 2005.[8] For the purposes of this chapter, the terms OKC and KOT will be utilized with relative equivalence.

Two variants of the OKC are well known; the sporadic cyst and the syndromic cyst associated with the nevoid basal-cell carcinoma syndrome. Both variants of the OKC are believed to be derived from remnants of the dental lamina. This cyst shows a different growth mechanism and biologic behaviour from the previously described dentigerous cyst. Most authors believe that dentigerous cysts continue to enlarge as a result of increased osmotic pressure within the lumen of the cyst. This mechanism does not appear to hold true for OKCs, and their growth may be related to unknown factors inherent in the epithelium itself or enzymatic activity in the fibrous wall.[9]

Adequate diagnosis and treatment of the OKC is important for three reasons: this cyst is recognized as being more aggressive than other odontogenic cysts,[10] the OKC has a higher rate of recurrence than other odontogenic cysts[11] and its association with nevoid basal-cell carcinoma syndrome requires that the clinician examine a patient with multiple cysts of the jaws for physical findings that might permit the diagnosis of this syndrome.[12–14]

OKCs may be found in patients from infancy to old age; however, 60% of cases are seen in people between 10 and 40 years old.[15] Although it is rare for a dentigerous cyst to appear multilocular on radiographs, it is most common for OKCs to appear multilocular (Figure 9.3). Some appear unilocular and can therefore be confused with dentigerous cysts. It is clear, therefore, that the differential diagnosis of a unilocular radiolucency must include both entities and that treatment of all unilocular radiolucencies should include curettage in the event that the diagnosis is later determined to be OKC. When more than one multilocular radiolucent lesion is noted on a panoramic radiograph, the clinician must consider the possibility of the presence of nevoid basal-cell carcinoma syndrome.

Similar to the treatment of other odontogenic cysts, the OKC is typically treated with enucleation and curettage and is ideally removed in one piece which requires acceptable access and lighting (Figure 9.4). An OKC/KOT that is radiographically multilocular ought to be biopsied pre-operatively. This exercise will permit a precise microscopic diagnosis due to the differential diagnosis of OKC/KOT vs. ameloblastoma. Despite controversy regarding whether the OKC/KOT represents a cyst or tumour, this approach to treatment seems to be non-controversial. As such, many patients are treated in an operating room setting under general anaesthesia. Under such circumstances, most sporadic OKCs are effectively managed with a thorough enucleation and curettage surgery.[16,17]

Figure 9.3 An odontogenic keratocyst (OKC) of the left mandible presenting as a multilocular radiolucency.

Figure 9.4 The specimen from the enucleation and curettage surgery for the OKC seen in Figure 9.3. Tooth no. 18 was removed to ensure complete removal of the cyst.

The reported frequency of recurrence of the OKC ranges from 2.5% to 62.5% in various studies.[11] This wide variation is likely related to the total number of cases studied, the length of follow-up periods, and the inclusion or exclusion of orthokeratinized cysts in the study group. Several reports that include large numbers of cases indicate a recurrence rate of approximately 30%.[1] Brannon has suggested three mechanisms responsible for recurrence: remnants of dental lamina within the jaws not associated with the original OKC being responsible for de novo cyst formation; incomplete removal (persistence) of the original cyst secondary to a thin friable lining and cortical perforation with adherence to adjacent soft tissue; and remaining rests of dental lamina associated with the original cyst and the presence of satellite cysts following enucleation.[18] Vedtofte and Praetorius reviewed 72 patients with 75 OKCs and observed remnants of dental lamina between the cyst membrane and overlying mucosa.[19] As such, they advocated the excision of overlying mucosa in conjunction with removal of the cyst. Other authors have recommended a primary

enucleation and curettage surgery for OKCs, including the use of methylene blue as a marking agent, followed by a 3-minute application of Carnoy's solution so as to reduce the chance for recurrence.[11]

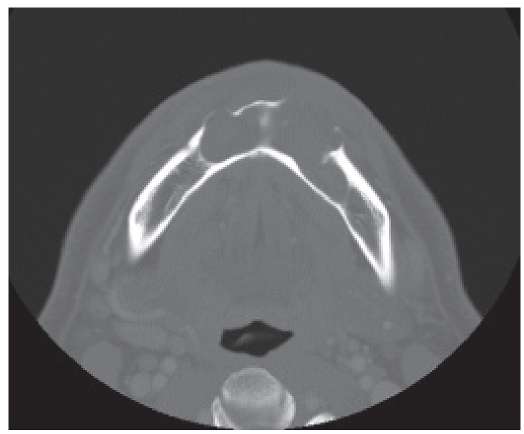
The orthokeratinized odontogenic cyst, once thought to be a variant of the OKC, is now generally well accepted as being a different clinicopathologic entity from the more common parakeratinized OKC. The orthokeratinized odontogenic cyst should therefore be placed in a different category. From the perspective of nomenclature, the parakeratinized cyst is referred to as a KOT while the orthokeratinized cyst is an OKC. These cysts usually appear as unilocular radiolucencies, but occasional examples have been multilocular. A majority of these cysts are encountered in a lesion that appears clinically and radiographically to represent a dentigerous cyst, most often involving an unerupted mandibular third molar tooth. Histologically, the epithelium is thin and orthokeratinized, and a prominent palisaded basal layer, characteristic of the OKC, is not present. Enucleation and curettage of the orthokeratinized cyst is curative in most cases. The reported rate of recurrence of 2% is far lower than the previously quoted statistics for recurrence of the OKC in general.[1]

Nevoid basal cell carcinoma syndrome

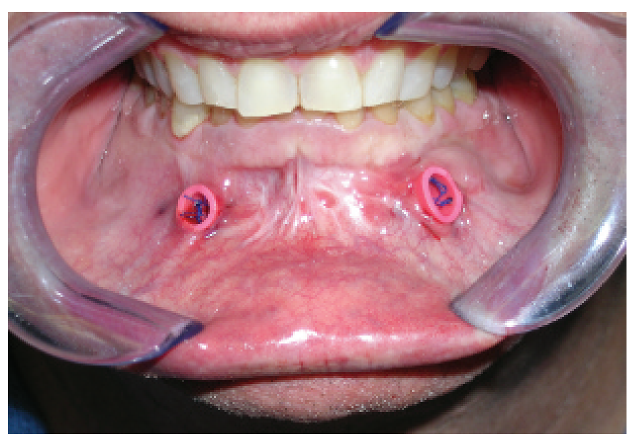
The nevoid basal cell carcinoma syndrome (basal cell nevus syndrome, Gorlin syndrome) is an autosomal-dominant inherited condition that exhibits high penetrance and variable expressivity. It is caused by mutations in the *PTCH* tumour suppressor gene, mapped to chromosome 9q22.3-q31. Observed hard and soft tissue anomalies include multiple basal cell carcinomas, frontal bossing, hypertelorism, mandibular prognathism, bifid ribs, lamellar calcification of the falx cerebri, palmar and plantar pitting and multiple OKC (Figure 9.5).[14] The discovery of multiple OKCs is usually the first manifestation of the syndrome that leads to the diagnosis. For this reason, any patient with an OKC should be clinically evaluated for this condition. Although the cysts in patients with nevoid basal-cell carcinoma syndrome microscopically resemble those not associated with the syndrome, they often demonstrate greater epithelial proliferation and daughter cyst formation in the cyst wall.

The treatment of the OKC in patients with nevoid basal-cell carcinoma syndrome can be difficult owing to the large number of 'recurrences' in these patients. As a matter of point, these 'recurrences' probably represent new primary cysts owing to the autosomal-dominant penetrance of the syndrome and cyst development.[20] Whatever the mechanism, a resection hardly seems to be warranted when managing a syndromic cyst. Marsupialization (Figure 9.6) is a

Figure 9.5 A coronal CT scan demonstrating radiolucencies of the right maxilla and left mandible. These were noted in a patient with hypertelorism, frontal bossing, multiple basal cell carcinomas and mandibular prognathism, thereby clinically and radiographically proclaiming nevoid basal cell carcinoma syndrome. Removal of both jaw cysts identified keratocystic odontogenic tumours (KOTs).



(a)



(b)

Figure 9.6 Marsupialization of a syndromic KOT will result in shrinkage of the lesion, and ultimately requiring an enucleation and curettage of the lesion. (a) The CT scan identifies a large multilocular radiolucency that crosses the mandibular midline. (b) Two 14-French red rubber catheters were placed in the lesion following suturing of the lesion's epithelium to the oral mucosa.

more desirable procedure that has been shown to result in at least partial resolution of the syndromic cyst. A definitive enucleation and curettage should be performed once radiographs demonstrate a significant decrease in the size of the cyst.[20]

Glandular odontogenic cyst

The glandular odontogenic cyst is a rare cyst of the jaws that is capable of aggressive behaviour and recurrence. Although it is generally accepted as being of odontogenic origin, it shows glandular or salivary features that seem to point to the pluripotentiality of odontogenic epithelium as cuboidal/columnar cells, mucin production and cilia are noted in these cysts. Glandular odontogenic cysts occur most commonly in middle-aged adults, with a mean age of 49 years at the time of diagnosis.[1] A majority of cases occur in the mandible, particularly the anterior mandible, with many mandibular lesions crossing the midline (Figure 9.7).[21] These cysts may appear either unilocular or multilocular radiographically.

There is a histologic similarity between the glandular odontogenic cyst and the predominantly cystic intraosseous mucoepidermoid carcinoma. However, the epithelial lining of the glandular odontogenic cyst is typically thinner and does not show evidence of the more solid or microcystic epithelial proliferations seen in mucoepidermoid carcinoma. Waldron and Koh reviewed the similarities between the two lesions and concluded that it is entirely possible that some cases previously diagnosed as central mucoepidermoid tumours may be reclassified as examples of glandular odontogenic cysts.[22] Most glandular odontogenic cysts are treated with enucleation and curettage. Some authors, however, point to a recurrence rate of approximately 30% and therefore recommend resection.[23]

Figure 9.7 A unilocular radiolucency is noted in the anterior mandible on this CT scan. Biopsy indicated glandular odontogenic cyst. (From Carlson ER. In: Miloro M (ed.), *Peterson's Principles of Oral and Maxillofacial Surgery*, 3rd edition, Shelton, CT: People's Medical Publishing House-USA, Chapter 29, 625–652, 2012.)

Calcifying odontogenic cyst

The calcifying odontogenic cyst (COC), or Gorlin cyst, is an uncommon lesion that demonstrates considerable histopathologic diversity and variable clinical behaviour. Although designated as a cyst, some investigators provide evidence for subclassification as a neoplasm as well.[24,25] In addition, the COC may be associated with other recognized odontogenic tumours, most commonly the odontoma. Adenomatoid odontogenic tumours and ameloblastomas have also been associated with the COC. Ghost cell keratinization, the characteristic microscopic feature of this cyst, is also a defining feature of the cutaneous lesion known as the calcifying epithelioma of Malherbe or pilomatrixoma. The World Health Organizational 2005 classification of odontogenic tumours groups the COC with all its variants as an odontogenic tumour rather than an odontogenic cyst.[8] Specifically, this lesion is referred to as a calcifying cystic odontogenic tumour. The review by Hong and colleagues designated 79 of 92 cases of COC as cysts with the remaining 13 cases being neoplastic in nature.[24]

The COC is predominantly an intraosseous lesion, although 13%–30% of reported cases occur as peripheral lesions.[1] Both the peripheral and central lesions occur with about equal frequency in the maxilla and mandible. There appears to be a predilection for the incisor and canine areas (Figure 9.8). Patients range in age from infant to elderly, with a mean age of occurrence of about 30 years. COCs that are associated with odontomas tend to occur in younger patients, with a mean age of 17 years.[1] The more rare neoplastic variant of the COC appears to occur in elderly patients. Most COCs appear radiographically as unilocular well-defined lesions. The radiopaque structures

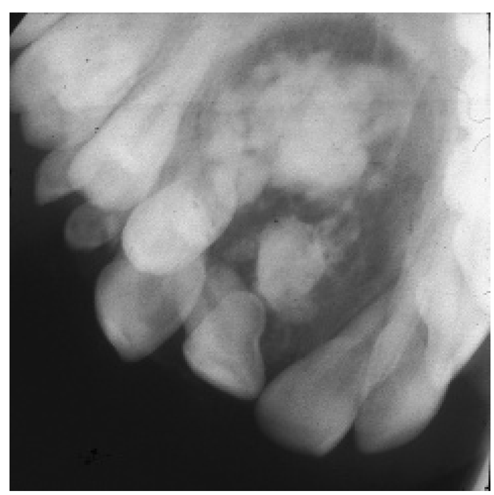


Figure 9.8 An occlusal radiograph demonstrating a mixed radiolucent/radio-opaque lesion of the anterior maxilla. The differential diagnosis should include calcifying odontogenic cyst (COC). (From Carlson ER. In: Miloro M (ed.), *Peterson's Principles of Oral and Maxillofacial Surgery*, 3rd edition, Shelton, CT: People's Medical Publishing House-USA, Chapter 29, 625–652, 2012.)

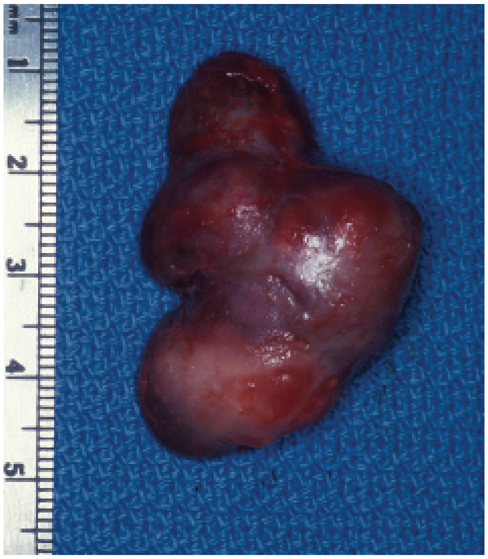


Figure 9.9 Enucleation and curettage of the lesion are performed of the lesion noted in Figure 9.8. Final pathology identified a COC and complex odontoma.

within the lesions have been described as either irregular calcifications or tooth-like densities (Figure 9.8).

The standard treatment for the COC is enucleation and curettage (Figure 9.9). A limited number of recurrences have been reported after such treatment. When a COC is associated with another recognized odontogenic tumour such as an ameloblastoma, the treatment and prognosis are likely to be the same as for the associated tumour. The rare neoplastic variant of the COC should be treated with resection.

CYSTS OF THE FACE AND NECK

Several cysts occur in the soft tissues of the face and neck. Developmental cysts of the neck are rare malformations that develop along embryonic fusion lines or from other embryonic remnants. Four pharyngeal clefts separating the branchial arches are noted in the 5-week-old embryo. The dorsal aspect of the first cleft penetrates the underlying mesoderm and results in the development of the external auditory meatus. Active proliferation of the mesodermal tissue of the second arch causes it to overlap the third and fourth arches. The second, third and fourth clefts temporarily form an ectoderm-lined sinus, the cervical sinus. Branchial cleft anomalies are believed to develop as a result of incomplete obliteration of the cervical sinus or from epithelial rests of the branchial clefts. These abnormalities include cysts, sinuses and fistulae. They typically occur in the lateral neck region, anterior border of the sternocleidomastoid muscle, or in the vicinity of the parotid gland and external ear.

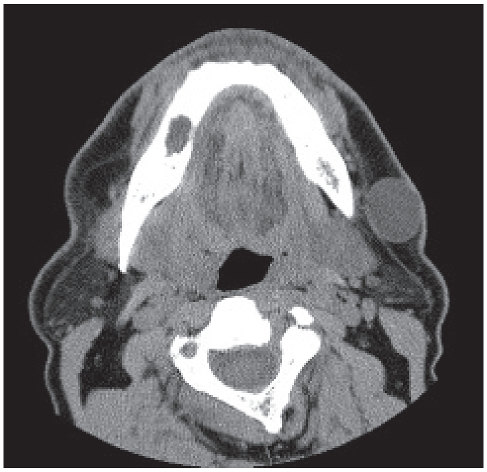
The term dermoid cyst is utilized to describe three histologically related developmental squamous epithelial lined cysts including the dermoid, epidermoid and teratoid cysts. A distinguishing characteristic of dermoid and epidermoid cysts is the presence of dermal appendages such as sebaceous glands and hair follicles within the wall of the dermoid cyst and their absence in the epidermoid cyst. Teratoid cysts are extremely rare in the head and neck region and contain structures from all three germinal layers such as nervous, gastrointestinal and respiratory tissues.

Epidermoid cyst

Epidermoid cysts are the most common cutaneous cysts. They can be found anywhere on the body, but are most commonly found on the trunk and face, specifically in mid-cheek (Figure 9.10) and pre-auricular areas. They are often incorrectly called sebaceous cysts but do not contain any sebaceous component. The walls are lined with stratified squamous epithelium and the cyst is often filled with keratin. These cysts often arise from trauma or surgery causing the epidermis to be implanted into the dermis. They are subcutaneous formations that are slow growing, firm, and rarely grow larger than 5 cm. There is no gender predilection and can be single or multiple in the head and neck. They are frequently found in individuals with a long history of chronic skin irritation such as acne or irregular skin complexions.

Epidermoid cysts are commonly diagnosed by their clinical appearance. These cysts are intradermal formations that rarely exceed growths that require imaging. Nonetheless, on CT scans, they are noted to be well circumscribed with fluid attenuation (Figure 9.11). These cysts are removed with surgical excision with frequent removal of skin with an elliptical excision (Figure 9.12). Recurrences are rare although patients may develop similar cysts in other areas of the facial or neck skin.

Figure 9.10 Clinical appearance of an epidermoid cyst of the left cheek.



(a)

(b)

Figure 9.11 (a and b) The CT scans of the patient in Figure 9.10 shows signs consistent with an epidermoid cyst.

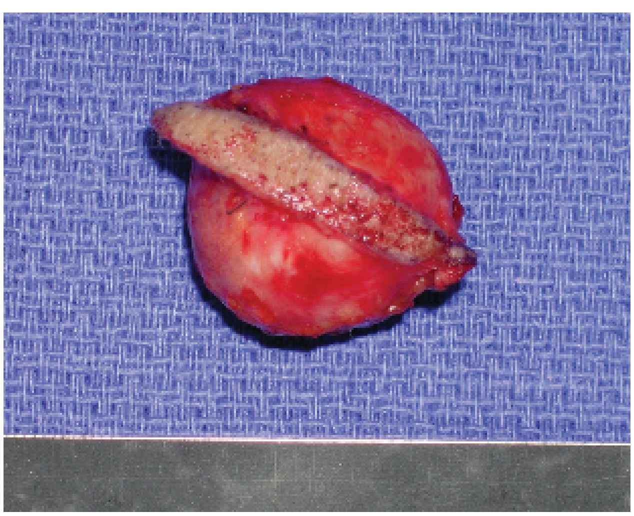


Figure 9.12 The specimen from the excision of the epidermoid cyst of the patient in Figure 9.10. Adherent overlying skin was sacrificed with the cyst.

Branchial cleft cyst

Branchial cleft anomalies account for 30% of all congenital neck masses that are commonly found in children and young adults with equal male-to-female predilection.[26] They are usually asymptomatic but can become painful if secondarily infected. These anomalies can enlarge over time and attain a very large size up to 10 cm. They are found anywhere from the pre-auricular region down to the supraclavicular fossa, lateral to the anterior border of the sternocleidomastoid muscle (Figure 9.13). They are usually firm, not easily moveable, and do not move with swallowing.

CT scans of non-infected branchial arch cysts typically appear as mucoid attenuation with a well-circumscribed smooth cystic lining (Figure 9.14). On magnetic resonance imaging (MRI), the signal intensity on T1 weighted images are low to intermediate, on T2 images signal intensity is

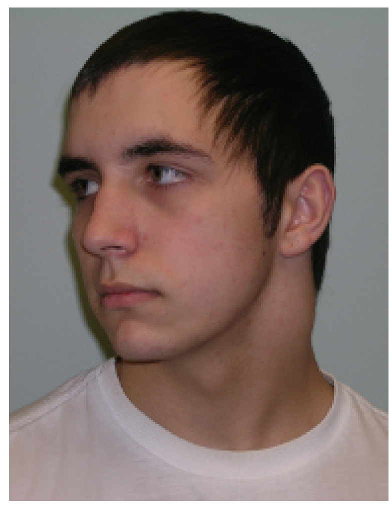


Figure 9.13 A 23-year-old man with a left lateral neck swelling. Branchial cleft cyst should be placed on the differential diagnosis primarily due to the patient's age and the location of the neck mass.

Figure 9.14 The CT scan of the patient in Figure 9.13 that shows signs consistent with the branchial cleft cyst.

high. Infection can lead to a thickened cystic wall that may become fibrotic which enhances with contrast.

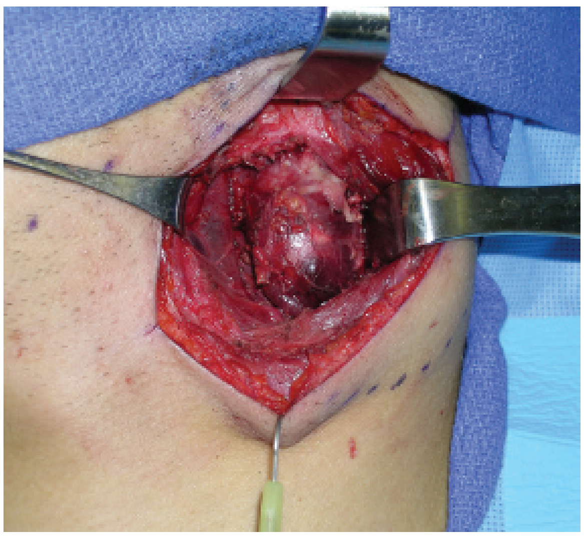
The treatment of choice for branchial cleft cysts is complete surgical excision in a non-inflamed cyst (Figure 9.15). A cyst with an acute infection should be treated with antibiotics and incision and drainage if necessary. Following resolution of the infection, complete removal is recommended and recurrence is rare.

Dermoid cyst

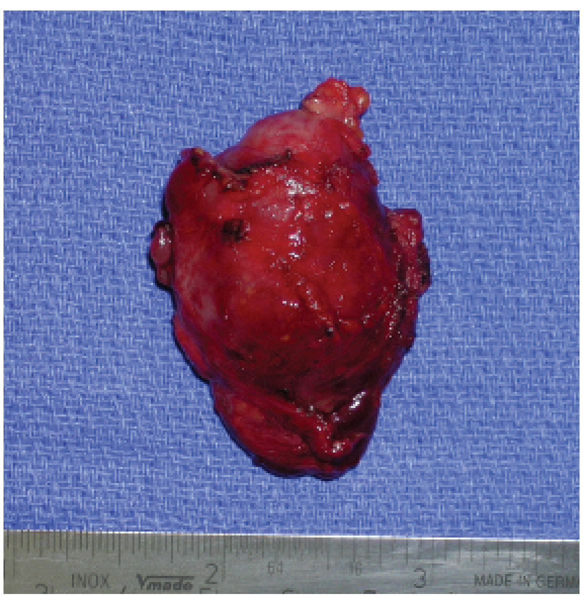
Dermoid cysts are uncommon developmental malformations in the head and neck that form when ectoderm becomes entrapped during the fusion of the first and second brachial arches during the fourth week of embryonic development. They are most common in the testes and ovaries and only 6.9% of dermoid cysts are found in the head and neck.[27] The epithelial-lined cyst cavities may contain hair follicles, sebaceous glands and other skin derivatives. Keratin and sebum may be present. They occur most commonly during the second and third decades of life but can be found at any age including newborns.[28] Clinically they are soft, encapsulated, doughy to palpation and sinus tracts are uncommon (Figure 9.16).[29]

In 1937, New and Erich classified the dermoid cyst as either congenital or acquired and divided it into three types.[30] The first type is a teratoma-like congenital mass most commonly found in the testicles or ovaries. The second type is an acquired cyst, caused by traumatic iatrogenic inclusion of epidermoid tissue most commonly found in the hand. The third type is a congenital inclusion cyst which develops during embryonic development in the head and neck. The majority of floor of mouth dermoid cysts are slow growing, midline and asymptomatic. They account for 1.6% of all dermoid cysts.[27] The position of the cyst in relation to the mylohyoid and geniohyoid muscles affects its clinical presentation. Hidden dermoid cysts in the floor of mouth can obtain a large size that impairs normal speech and swallowing, and can cause partial obstruction of the airway. These cysts should always be removed as early as possible in newborns and young children to prevent these potential airway complications. The differential diagnosis should include a plunging ranula, an odontogenic infection, salivary gland tumour and obstruction of the submandibular duct.

If located in the midline neck, dermoid cysts can be differentiated from a thyroglossal duct cyst by its fixed nature



(a)



(b)

Figure 9.15 (a and b) Excision of the lesion was performed and final histopathology confirmed the diagnosis of branchial cleft cyst.

Figure 9.16 A submental mass is present in a 25-year-old male. The anatomic location of the mass suggests the presence of a dermoid cyst. The cyst was excised and final histopathology confirmed the presence of dermoid cyst. (From Carlson ER and Kang E, *Odontogenic and Non-Odontogenic Cysts*, American Association of Oral and Maxillofacial Surgeons Knowledge Update. Rosemont, IL: American Association of Oral and Maxillofacial Surgeons.)

during swallowing and tongue protrusion. In the neck, the differential diagnosis should include a thyroglossal duct cyst, cystic hygroma, lymphoma, thyroid mass or cervical lymphadenopathy.

CT scans show a unilocular and well-defined cystic mass with a fluid-filled lumen with low attenuation. Fatty internal material may be present giving a mixed density of fluid contents. On MRI, T1 weighted images will have diffuse high signal intensity. On T2 weighted images, there will be heterogeneous high signal intensity caused by fat and calcifications.

The treatment for dermoid cysts is complete surgical excision. Recurrence does not occur if the cyst and associated tract are completely excised. For submental cysts arising above the mylohyoid muscle, a transoral incision may be used. For cysts arising below the mylohyoid muscle, a transcutaneous incision is recommended to permit better surgical access. Subcutaneous dermoid cysts may have deep tracts that can be adherent to underlying periosteum and other bony structures. Meticulous surgical technique must be used during removal because of the cyst's adherence to adjacent tissue that may lead to inadequate excision. Malignant transformation has been reported but is rare.[31]

Top tips

- If the diagnosis is in doubt aspirate.
- With any extensive lesion consider a pre-operative biopsy.
- Assess patient compliance if considering conservative management.
- Long-term follow-up is essential for OKCs.

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10

Basic implantology – An American perspective

JAIME BRAHIM

CONTENTS

INTRODUCTION

The history of tooth replacement goes back to ancient civilization. The earliest attempts at tooth replacement with dental implants were in the Mayan civilization dating back to 600 AD. Ancient skulls have been discovered in which teeth were replaced by materials ranging from carved stones, bamboo sticks and ivory, to fragments of seashells. It was not until the work of Professor Branemark in Sweden in the early 1950s, that biocompatibility of dental implants in experimental studies in animals was demonstrated. The depth of the scientific research, specifically in titanium implants, was the work of the group led by Per-Ingvar Branemark an orthopaedic surgeon. His work defined osseointegration. Osseointegration was originally defined as a direct structural and functional connection between ordered living bone and the surface of a load-carrying implant. It is now said that an implant is regarded as osseointegrated when there is no progressive relative movement between the implant and the bone with which it has direct contact. In practice, this means that in osseointegration there is an anchorage mechanism whereby non-vital components can be reliably and predictably incorporated into living bone and that this anchorage can persist under all normal conditions of loading. This definition of osseointegration has formed the basis for today's implantology science.

The clinical replacement of lost natural teeth by osseointegrated implants represents one of the most significant advances in dentistry.

DIAGNOSIS AND TREATMENT PLANNING

The key to the success of implant treatment is collating appropriate information that will result in a well thought out, performed and successful procedure. It is essential for the surgeon to understand the patient's chief complaint and why they want dental implants. Providing the patient with detailed information including that about possible long-term complications is equally important.

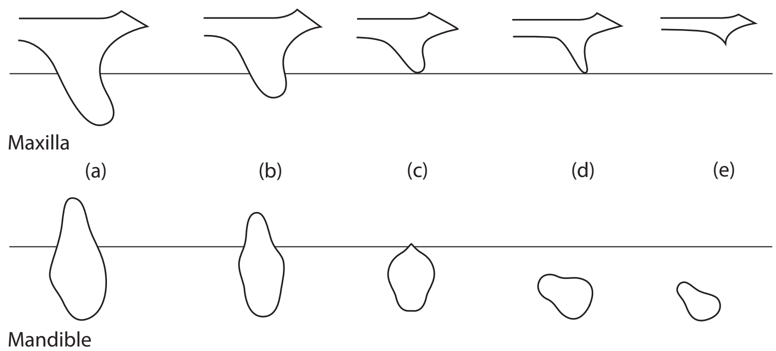

Figure 10.1 Lekholm and Zarb, degrees of resorption. (a) Most of the alveolar bone is present. (b) Moderate residual ridge resorption has occurred. (c) Advanced residual ridge resorption has occurred and only basal bone remains. (d) Some resorption of the basal bone has taken place. (e) Extreme resorption of the basal bone has taken place.

A good patient assessment plan should include the following:

- *Medical, dental and social history:* Medical evaluation is vital in implant surgery especially because the treatment is often provided for an older segment of the population. Review of the risks and benefits of the treatment plan should be discussed with the patient. Patients that are immunocompromised or smoke heavily should expect a lower success rate than other patients for example. Medications such as bisphosphonates and other antiresorptive drugs can also have a significant impact.
- *Extraoral and intraoral examination:* A complete examination of the head and neck is vital. Facial symmetry, smile line, tooth show, midline relation and occlusal plane should be evaluated. Intraoral examination should include the condition of the mucosal tissues, the condition of the remaining dentition and the quality and quantity of maxillary and mandibular bone.
- *Radiographic examination:* Intraoral periapical radiographs are very helpful in assessing the space between adjacent teeth and the direction of the adjacent roots. The advantages of periapical radiographs are low radiation dose, high resolution and they are inexpensive. The limitations are distortion and magnification, minimal site evaluation and lack of cross-sectional imaging. Computerized tomography (CT) scans provide much more information and allow a more detailed evaluation, especially of structures such as the mandibular canal and the antrum.
- *Articulated study casts:* The value of diagnostic casts is critical in oral implantology as they provide essential information about occlusal centric relation, number of missing teeth, space between the adjacent teeth and the inter-arch space for the implant and restoration.
- *Photographic records.*
- *Surgical plan.*
- *Template for surgery:* A well-made template assists the operator in the correct placement of the dental implant. It is important that the template fits securely, and gives appropriated access to the drill to prepare the implants sites.
- *Signed consent form:* Assures the surgeon that patients completely understand the surgical treatment and its complications.

ASSESSMENT OF BONE QUANTITY AND QUALITY

Every tooth extraction leads to remodelling of the alveolar bone, and bone loss, that is greater during the first 3 months. Remodelling is mostly complete after 1 year. Bone loss occurs in both the vertical and horizontal planes.

The surgeon should be able to assess bone quality and quantity. An elegant description is the one proposed by Leholm and Zarb (Figures 10.1 and 10.2).

Assessment of bone ***quantity*** *by Leholm and Zarb* (Figure 10.1) is as follows:

1. Most of the alveolar bone is present.
2. Moderate residual ridge resorption has occurred.
3. Advanced residual ridge resorption has occurred and only basal bone remains.
4. Some resorption of the basal bone has taken place.
5. Extreme resorption of the basal bone has taken place.

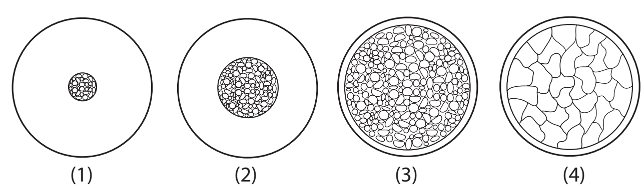

Figure 10.2 Lekholm and Zarb bone quality classification. (1) Almost the entire jaw is comprised of homogenous compact bone. (2) A thick layer of compact bone surrounds a core of dense trabecular bone. (3) A thin layer of cortical bone surrounds a core of dense trabecular bone of favourable strength. (4) A thin layer of cortical bone surrounds a core of low-density trabecular bone.

Assessment of bone ***quality*** *by Leholm and Zarb* (Figure 10.2) is as follows:

1. Almost the entire jaw comprises homogenous compact bone.
2. A thick layer of compact bone surrounds a core of dense trabecular bone.
3. A thin layer of cortical bone surrounds a core of dense trabecular bone of favourable strength.
4. A thin layer of cortical bone surrounds a core of low-density trabecular bone.

ANATOMIC CONSIDERATIONS FOR DENTAL IMPLANTS

Maxilla

The maxillary bone is a hollow cuboid shape that houses the teeth, forms the roof of the oral cavity, forms the floor of and contributes to the lateral wall and roof of the nasal cavity, houses the maxillary sinus and contributes to the inferior rim and floor of the orbit. Two maxillary bones are joined in the midline to form the middle third of the face.

Performing implant surgery in the maxilla requires a detailed knowledge of the anatomical landmarks, such as the maxillary sinus, the nasal cavity, the nasopalatine canal, midline suture, cortical shell (especially when deficient). Appreciation of diminished vertical and horizontal dimensions is essential as well.

Mandible

The operator should be familiar with the effects of the loss of teeth, the effect and possible extent of the alveolar bone resorption and also be familiar with the anatomical areas of the mandible such as the body region, the exact location of the inferior alveolar nerve, the region of the symphysis and of the mental nerve. The mental nerve before exiting through the mental foramen may form a loop that runs anterior and inferior to the foramen. This loop can extend from 1 to 7 mm. Generally, the mandibular canal runs from the mandibular foramen inferiorly and anteriorly, then runs horizontally and laterally most of the time just below the roots apices of the molars. When placing implants in the area close to the inferior alveolar nerve, clearance of at least 2 mm from the most superior aspect should be allowed to prevent surgical trauma.

Knowledge of the concavities of the mandible especially in the lingual region is important to avoid any perforation whilst drilling that may produce a significant bleeding from the sublingual vessels (Figure 10.3).

IMPORTANT ASPECTS TO INCREASE IMPLANT SURGICAL SUCCESS

1. Sterile technique, to minimize the risk of infection
2. Oral rinsing with 0.2% chlorhexidine prior to surgery
3. Gentle surgical technique
4. Light and intermittent drilling pressure (Figures 10.4 and 10.5)
5. Copious cooling irrigation
6. Avoid contamination of implant surfaces with gloves, tubing etc.
7. Well-trained staff

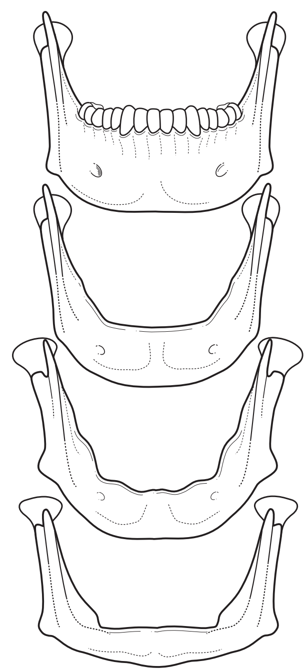

Figure 10.3 Different levels of mandibular resorption.

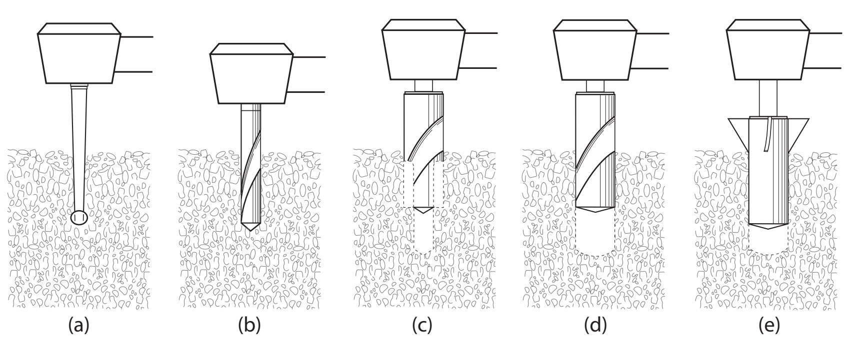

Figure 10.4 Steps in the preparation of implant osteotomy slides.

SURGICAL PROCEDURES

Mandible

After administration of local anaesthetic and sedation as required, two different incision designs can be performed in the anterior mandible:

- *Crestal incision* is made when the mandible has adequate height and the muscle fibres are inserting below the alveolar crest. When patient has healthy attached gingiva a crestal incision provides a good access to labial and lingual regions (Figure 10.6).
- *Vestibular incision* is made for patients with poor attached gingiva or when the insertion of the muscle is high (Figure 10.7).

Both incisions must follow the principles of good incision design (adequate access and visibility to allow identification of important anatomical landmarks such as mental foramina, incisal canal etc., and a mucoperiosteal flap that provides good vascular supply). A careful blunt dissection is required to identify anatomical landmarks.

After the surgical template is positioned, a sterile pencil is used to mark the position of the implant in the bone.

After the flap is raised, with copious irrigation and a high speed (maximum 2000 rpm), the bone preparation can be initiated following the instructions of the different implant manufacturers. Most implant systems provide the surgeon with several drill sizes that will allow the gradual enlargement of the surgical site. The drilling should be done with the intermittent technique, always having new sharp burs and copious irrigation.

When the osteotomy site is prepared, using a low speed of 15–20 rpm, the implant is placed. Then the healing abutment or cover screw is positioned. If there is good stability of the implant, a healing abutment can be placed immediately. Otherwise, a cover screw must be placed so that the implant can be buried and later uncovered during Stage II surgery. At the end of the procedure, the surgical area is irrigated and a primary closure is performed with 3-0 or 4-0, silk or vicryl sutures (Figures 10.8 through 10.14).

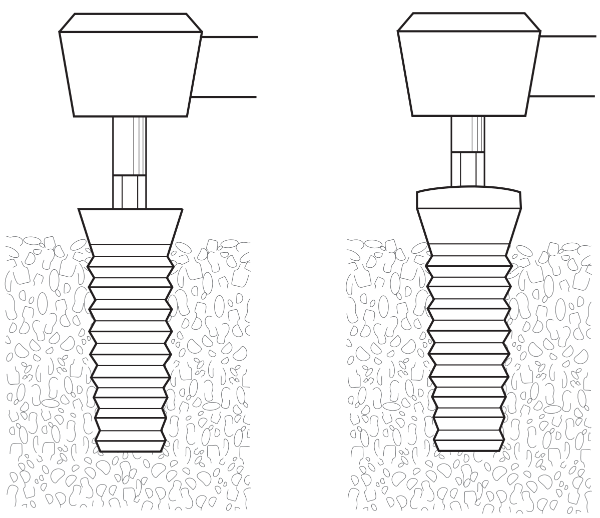

Figure 10.5 Implant insertion and cover screw placement.

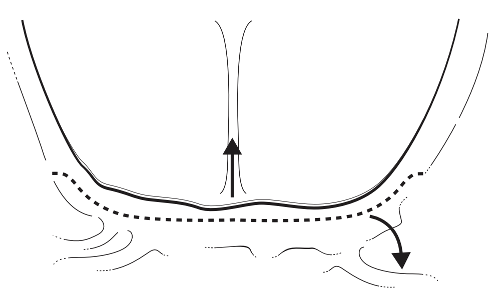

Figure 10.6 Crestal incision.

Maxilla

After administration of local anaesthetic and sedation as required, an incision that is slightly palatal to the alveolar crest is made. This incision design will allow the surgeon to visualize the palatal bone contours. After the flap is raised, the osteotomy of the implants sites is performed. In the maxillary arch, sometimes it is possible to establish bicortical stability in the area of the sinus and nasal bone, being careful that only the apical tip of the implant engages the cortical plate. Then, the healing abutment or cover screw is placed. If there is good stability of the implant, a healing abutment can be placed immediately. Otherwise, a cover screw must be placed so that the

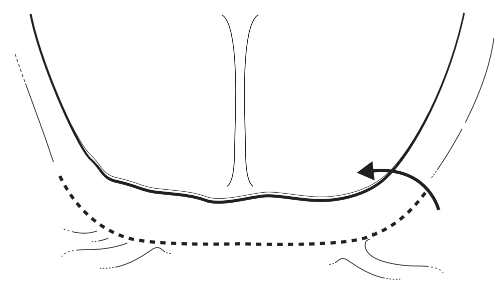

Figure 10.7 Vestibular incision.

Figure 10.8 Pre-operative view of a mandible demonstrating a knife ridge.

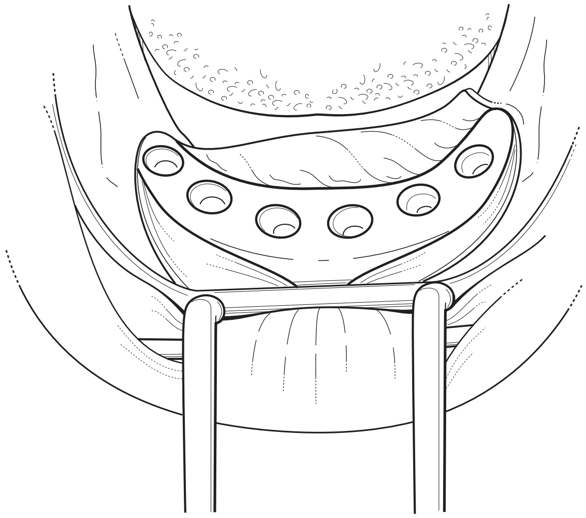

Figure 10.9 Final preparations of the implant sites showing a favourable distance from each other.

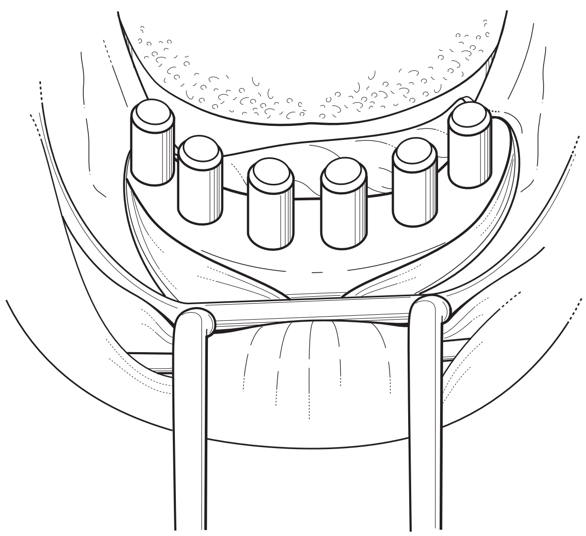

Figure 10.10 Clinical picture showing good parallelism of the abutment.

implant can be buried and later uncovered during Stage II surgery. At the end of the procedure, the surgical area is irrigated and a primary closure is performed with 3-0 or 4-0 silk or vicryl sutures.

POST-OPERATIVE CARE

- *Antibiotics:* Studies have shown similarly improved success rates in implant placement with the use of both pre-operative and post-operative antibiotic prophylaxis as compared to no antibiotics. Risks and benefits of antibiotic therapy must be evaluated for each case to determine whether specific indications exist for the use of antibiotic prophylaxis. If an infection develops post-operatively, a 1-week course of a broad-spectrum beta-lactam antibiotic should be prescribed.

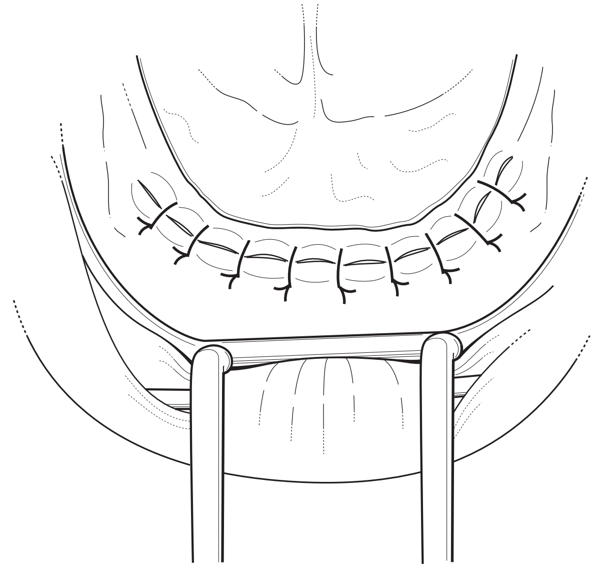

Figure 10.11 Primary closure of the incision using reabsorbable suture.

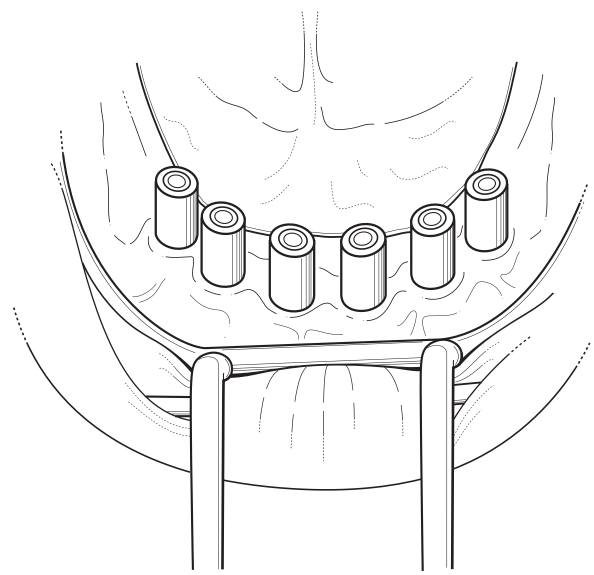

Figure 10.12 Note that abutments are parallel and ready for prosthetic rehabilitation.

- *Analgesics:* Patients usually only require Ibuprofen 400 mg every six hours. If the implant procedure is more involved, a combination of an anti-inflammatory analgesic with codeine or paracetamol usually suffices.
- *Oedema:* Post-operative, mild oedema is sometimes present and generally settles uneventfully. Use of steroids intra-operatively and post-operatively can be considered for selected cases.
- *Local care:* Meticulous oral care with gentle rinses of 0.2% chlorhexidine four times daily for 2 weeks, and gently brushing with a soft tooth brush, being careful with the operative site.
- *Diet:* A diet high in proteins and soft in texture that does not cause injury to the surgical sites should be advised.

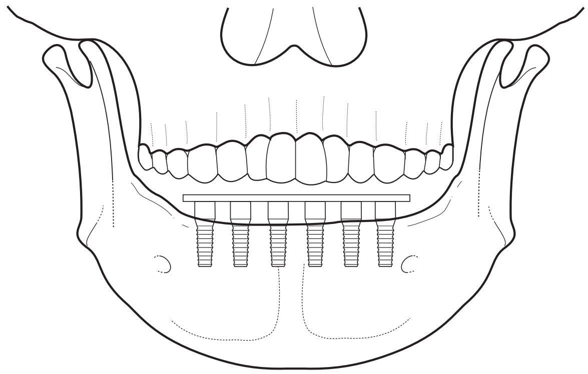

Figure 10.13 From view of integrated implants supporting mandibulary fixed-detachable prosthesis.

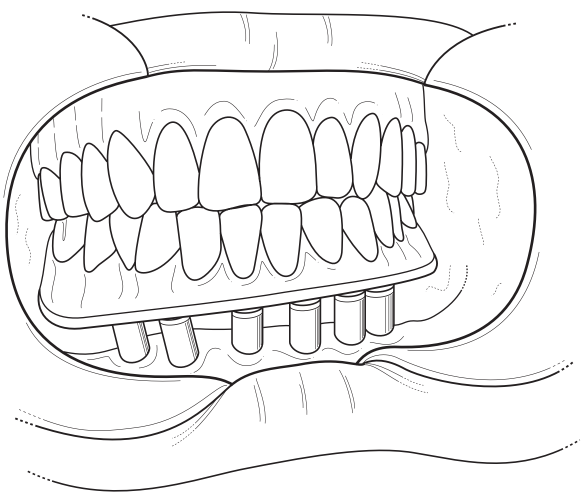

Figure 10.14 Three months after stage two implants have integrated and ready for implant-borne and screw-retained prosthesis, the prosthesis is removable by the dentist.

SECOND-STAGE SURGERY

This is only performed if a two-stage technique has been selected with the implant submerged and left to osseointegrate. During the second stage, the head of the implant body is exposed and the transmucosal abutment is placed. Usually, this procedure is carried out under local anaesthesia and the incision is made directly over the implant head and a small flap is raised, the cover screw removed and the appropriate healing abutment is secured on the implant. The flap is then repositioned and sutured.

POST-OPERATIVE CARE

Written post-surgical instructions for oral surgery should be given to the patient. If the patient is wearing dentures and a crestal incision was performed, wearing of dentures is acceptable during healing period. If a vertical incision was performed, it is advisable for the patient not to wear the denture immediately. It is always necessary to examine the patient 1 week later for possible suture removal, irrigation and any denture adjustment.

IMMEDIATE IMPLANTS

Traditionally, before placing a dental implant the teeth are removed and the extraction sockets are left to heal for several months prior to the placement of an implant. Patients and doctors like, where feasible, to shorten the time between tooth extraction and implant placement. The potential advantages of immediate or early placement of an implant result in fewer surgical treatments and shorter treatment time. Bone loss is part of the normal remodelling phase after extraction, but might be reduced to advantage with an early implant placement, which can enhance the aesthetic result. The potential disadvantages are increased risk of infection, implant failure, difficulties in achieving primary stability and gaps can be present between the implant and the bony walls of the socket.

Several publications and reviews have been published on survival and success rates of implants placed immediately into a fresh extraction socket or early placement (Slagter 2014; Lang 2011; Esposito 2010. A Cochrane review).

Esposito, in a Cochrane review identified 14 eligible randomized controlled trials (RCTs) evaluating the success, complications, aesthetics and patient satisfaction between 'immediate (same day)', immediate delayed (10 days) and delayed implants (3 months) to evaluate whether and when augmentation procedures are necessary and which is the most effective technique.

The authors conclude that there is insufficient evidence to determine possible advantages or disadvantages of immediate, immediate-delayed or delayed implants. The authors add that these preliminary conclusions are based on a few underpowered trials. There is a suggestion that immediate and immediate-delayed implants may have a higher risk of implant failure and complications than conventional delayed implants. On the other hand, the aesthetic outcome might be improved when placing implants just after teeth extraction. They report that there is not enough reliable evidence supporting or refuting the need for augmentation procedures at the time of immediate implant placement in fresh extraction sockets or whether any of the augmentation techniques are superior others.

BONE GRAFTING

Bone grafting can be performed at the time of surgery if the defects are small. The graft in these cases is usually taken from an intraoral site, such as

1. From the anterior mandible (chin).
2. Retromolar area of the mandible.

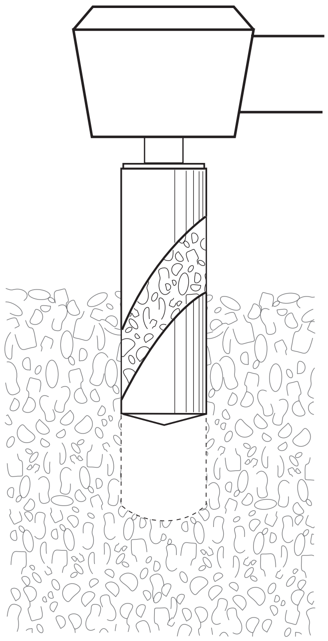

Figure 10.15 Bone bits trapped in the bur can be used as autologous graft.

3. Bone can also be retrieved for the graft from the drilling site by using a bone collector either from the suction line or from the drill bits (Figure 10.15).

Other areas to obtain autologous bone grafts are as follows:

1. Iliac crest
2. Cranium
3. Tibia

Autografts are the preferred source of bone material due to the lack of antigenicity of the graft material. In addition, we can use Allografts that are obtained from a human cadaver. The clinical success of these grafts is well proven. The advantage of allografts is that there is not an additional surgical procedure to obtain the bone. Xenografts are grafts from one species to another, e.g. bovine bone; they are useful when mixed with the patient's blood. Alloplastic grafts are synthetic bone substitute that may act as a framework for bone formation. Bone morphogenic protein (BMP) has recently been approved by the U.S. Food and Drug Administration for use in bone grafting. These molecules act to signal stem cells that migrate to the site of the graft and differentiate into osteoblasts which lay down new bone.

COMPLICATIONS

Stage-one surgery

1. *Haemorrhage during drilling.* This most often occurs after perforation of the lingual cortex of the mandible. Sometimes, bleeding can advance into the floor of the mouth, producing a threat to the patient's airway, necessitating emergency treatment.
2. *Implant mobility.* Not being able to obtain stability is usually due to poor bone density or over preparation of the implant site.
3. *Exposed implants threads.* The possible causes may be due to narrow crest.
4. *Paraesthesia.* Trauma to the nerves in the area of the implant placement is the usual cause.
5. Infection is unusual in implant surgery if a sterile technique is used.

Stage-two surgery:

1. *Failure to integrate.* Usually, presenting as a painful and mobile implant. The reasons for this complication can be multifactorial. Poor clinical evaluation for surgical site, poor surgical technique, infection or a lack of experience are the usual causes. The solution is removal of the implant.
2. *Difficulties placing the abutment.* Possible causes include damage to internal features of the implant body during placement of the implant, and bone overgrowth during the healing process.

Top tips

- In order to preserve the interproximal dental papilla it is important to have at least 3 mm between implants, and 1.5 mm between natural tooth and implant.
- Implants should be placed at a minimum of 2 mm from the inferior alveolar canal or below the maxillary sinus.
- Gentle surgical technique, light and intermittent drilling pressure and copious cooling irrigation, is important factors to increase implant surgical success.
- The amount of bone needed buccal and lingual to the implant (width) is a minimum of 1.5 mm of cortical bone.
- A good incision design should have good access and visibility to allow identification of important anatomical landmarks, and have a good mucoperiosteal flap that provides good vascular supply.
- Immediate placement of implants may result in improved aesthetics through maintenance of soft tissue architecture and contours.

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Adjunctive office-based techniques for bone augmentation in oral implantology

GARY WARBURTON and ABHISHAKE BANDA

CONTENTS

GENERAL PRINCIPLES

Adequate bone stock is essential for successful implant placement. Deficient bone may arise due to physiologic resorption in edentulous areas or acquired defects secondary to trauma or ablative surgery. There are numerous augmentation materials and techniques available if the bone volume is inadequate at the planned implant site. Many factors influence the selection of augmentation material and technique; however, the volume, location and morphology of the defect are primary determinants.

Classification of grafting materials

- *Autogenous bone:* Harvested from the patient
- *Allogenic:* Typically harvested from cadavers
- *Xenogenic:* Harvested from a different species (e.g. porcine or bovine)
- *Alloplastic:* Inert or synthetic materials

These materials may be used individually or in combination to replace and/or regenerate deficient bone. They may also be supplemented by biologically active materials such as platelet-rich plasma (PRP) and bone morphogenic proteins (BMPs). Autogenous bone remains the gold standard graft material, since it possesses osteogenic, osteoinductive and osteoconductive properties, whereas allografts have only osteoconductive and possibly inductive properties, and alloplasts are merely osteoconductive. This chapter focuses on autogenous augmentation techniques that can be performed in the office or outpatient clinic environment.

Selection of the appropriate donor site is determined by many factors including the volume and the type of bone required (cancellous or corticocancellous). Potential donor sites suitable for office or outpatient clinic bone harvesting include local sites in the maxilla and mandible or remote sites such as proximal tibia. It should be recognized that mandibular and maxillary donor sites provide only a limited source of cancellous bone. It is reported that membranous bone grafts show less resorption than grafts harvested from endochondral bone. Although cancellous grafts vascularize more rapidly than cortical grafts, cortical grafts harvested from membranous bone vascularize more rapidly than endochondral bone grafts with a thicker cancellous component. Figure 11.1 shows the potential donor sites in the maxilla and mandible. Table 11.1 outlines the potential bone stock of different donor sites.

Instrumentation

The osteotomies allowing harvest of the autogenous graft from the donor site may be performed using traditional burs, saws, discs, trephines and osteotomes or using recent technology such as piezosurgery. Piezosurgery utilizes a range of working tips that oscillate at ultrasonic frequencies of around 10–60 Hz, thereby cutting bone while preserving soft tissue (nerves, sinus lining, blood vessels and mucosa). The reported advantages of piezosurgery over

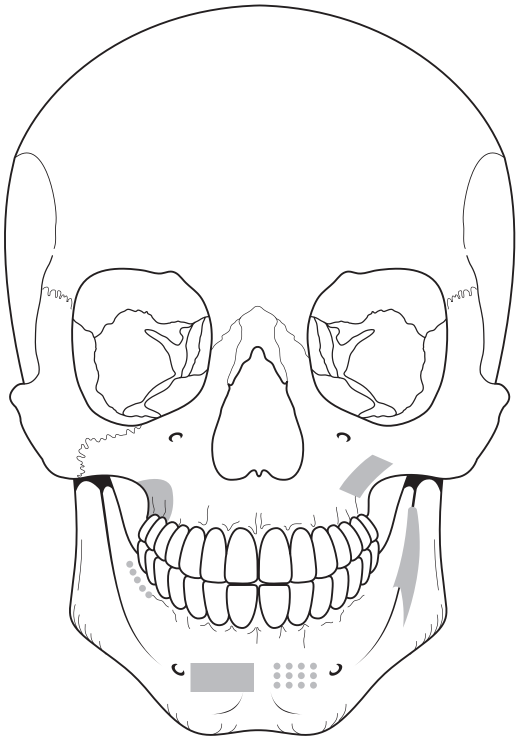

Figure 11.1 Donor sites in the maxilla and mandible.

Table 11.1 Potential donor sites in the maxilla and mandible.

Site	Potential bone volume (ml)
Cortical shavings from maxilla/mandible	2–5
Bony exostoses/tori	Variable
Suction-line bone traps	Variable
Mandibular symphysis	5
Mandibular ramus	5–10
Calvarial shavings	10–14
Proximal tibia	20–40
Anterior iliac crest	50
Posterior iliac crest	50–100

traditional rotary instruments are that there is no thermal injury or adjacent bone necrosis and the osteocytes remain viable at the osteotomy site. Therefore, healing takes place more rapidly, with little or no inflammation and without the need for an osteoclastic phase.

DONOR SITES

Mandibular symphysis

The mandibular symphysis presents a convenient donor site for corticocancellous bone due to its proximity to the recipient site. There is a limited supply of cancellous bone in this region, but there is adequate cortical bone stock to augment up to 1.5–2 cm in length, 1 cm in height and 4–7 mm in thickness. Some reports suggest superior bone quality at the grafted site when the bone is harvested from the symphysis compared to other sites including the iliac crest.

Pre-operative preparation

Panoramic and lateral cephalometric radiographs are adequate to assess the volume of bone available within the anatomic constraints described later. Tomograms and computed tomography (CT) scans may add more information regarding bony undercuts and deficiencies. Local mouth preparation should include chlorhexidine mouth rinse pre-operatively. This procedure may be performed under intravenous sedation or local anaesthetic.

Procedure

Local anaesthetic (2% lidocaine with 1:100,000 epinephrine may be mixed with 0.5% bupivicaine) is administered either as bilateral inferior alveolar and lingual nerve blocks, or as bilateral mental nerve blocks supplemented with labial and lingual infiltrations. Many surgeons use a perioperative antibiotic that is administered either enterally or parenterally before surgery. Access to the symphysis can be achieved either by a vestibular/labial incision 5–7 mm below the mucogingival junction or by a sulcular/crestal incision (Figure 11.2). A potential disadvantage of the sulcular incision is that it may result in bone resorption at the crest if the labial bone is thin and therefore reliant on the overlying periostium for its blood supply. In this situation, or when there is pre-existing marginal bone loss at the alveolar crest due to periodontal disease, a vestibular/labial approach is preferred.

For the vestibular/labial approach, a genioplasty incision is made in the vestibular mucosa extending from canine to canine. The incision is carried through the mucosa and submucosa until the bellies of the mentalis muscle are reached. These bellies may need to be divided depending on the level of the mentalis origin, to give access to the underlying symphyseal and parasymphyseal region of the mandible. The mentalis muscle is then detached from the anterior mandible using a periostial elevator or bovie electrocautery, and the soft tissues are elevated inferiorly down to the inferior border of the mandible in the subperiosteal plane. The required length of the bone graft dictates the lateral extension of the dissection. With larger corticocancellous blocks, it may be necessary to expose and identify the mental nerves. If a sulcular/crestal incision is made, it is necessary to create distal releasing incisions through the mucosa to allow adequate retraction of the flap as far inferiorly as the lower border of the mandible.

Once the anterior mandible is fully exposed down to the inferior border, there are some important anatomic constraints that should be outlined prior to performing the osteotomies (Figure 11.3). The superior horizontal

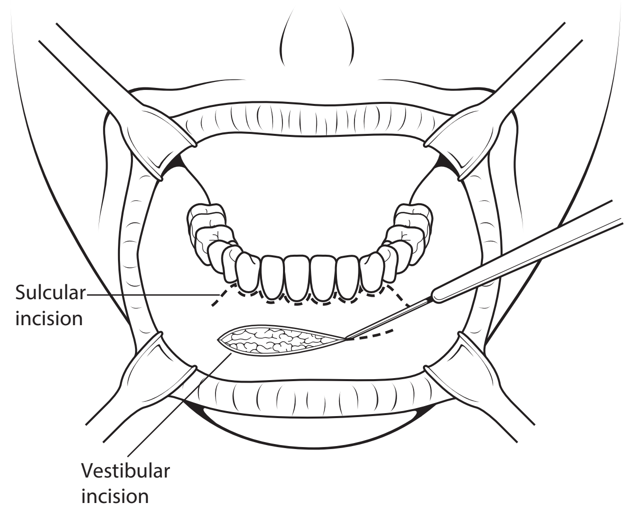

Figure 11.2 Access incisions for the mandibular symphysis.

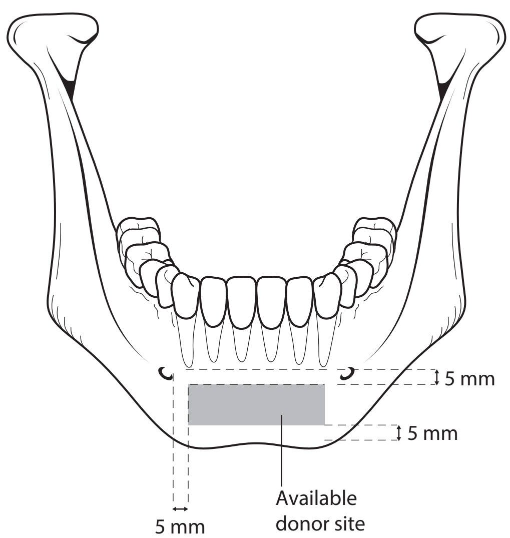

Figure 11.3 Mandibular symphysis donor site.

osteotomy should remain at least 5 mm inferior to the incisor and canine apices. The inferior horizontal osteotomy should maintain at least 5 mm of intact cortical bone at the inferior border. If the lateral osteotomies need to be placed close to the mental foramina for larger grafts, 5 mm of bone should remain anterior to the foramen, as the mental nerve may course anteriorly prior to exiting the mental foramen.

Bone may be harvested from the anterior mandible within these anatomic boundaries either using trephines to obtain multiple cores of corticocancellous bone (maintaining the integrity of the lingual cortex), or using small fissure burs, saws or piezosurgery tips to outline a block of corticocancellous bone. A midline vertical osteotomy may also be made to facilitate easy removal of two blocks of bone. The bone graft is then removed by completing the osteotomies with curved osteotomes. Small amounts of additional cancellous bone can be harvested up to the lingual cortical plate using curettes.

Once the bone is harvested, the bony defect may be filled with allogenic bone or collagen soaked in BMP (BMP-2 or BMP-7) and covered with a resorbable membrane. This minimizes the bony defect after the healing phase compared to simply closing the soft tissues without grafting the donor site. The soft tissues are closed in layered fashion, resuspending the bellies of the mentalis muscles prior to closure of the mucosal incision with either non-resorbable or resorbable sutures.

Post-operative management

A genioplasty dressing may be applied to provide additional support during the initial healing phase. Appropriate analgesics (non-steroidal anti-inflammatory and narcotic) are prescribed and most surgeons continue antibiotic therapy (amoxicillin or clindamycin) for 5–7 days. The patient should use saline rinses after meals. After 48 hours the patient should use chlorhexidine mouthwash for 2 weeks, in addition to saline rinses after meals. The diet should be restricted to a clear liquid diet for 24 hours and advanced to a soft mechanical diet for 2 weeks, to minimize the risk of wound dehiscence.

Complications

Possible complications include bleeding, hematoma, infection, wound dehiscence, nerve injury (mental nerve or its branches), incisor/canine tooth devitalization and mandible fracture. However, these complications can be minimized by careful surgical technique and post-operative care.

Mandibular ramus

The external oblique ridge of the mandibular ramus is another convenient site for bone harvest. A corticocancellous block of bone measuring up to 3 cm in length and 1 cm in height may be obtained from the ramus, although the thickness of bone is limited to approximately 4 mm due to the underlying inferior alveolar nerve. The dimensions of the ridge determine the potential size of the graft. This procedure may be performed under intravenous sedation or local anaesthetic.

Pre-operative preparation

Panoramic radiographs are adequate to assess the volume of bone available and the location of the inferior alveolar nerve. Tomograms and CT scans may add more information regarding bony undercuts, deficiencies and tooth root position. Pre-operative chlorohexidine preparation and perioperative antibiotics are used.

Procedure

Local anaesthetics are administered intraorally for inferior alveolar nerve block and infiltrative anaesthesia. The external oblique ridge is accessed through a linear mucosal incision starting at the level of the occlusal plane and extending down into the buccal vestibule as far forward as the first molar region. Alternatively, an incision starting on the external oblique ridge and extending crestally to the distal aspect of the last standing molar and then turning down into the vestibule as far forward as the first molar. Periostial elevators are used to elevate a buccal mucoperiostial flap, and also reflecting the lingual flap giving clear visualization of the superior ramus and external oblique ridge. Traumatic or supraperiosteal lingual flap elevation may cause lingual nerve injury. The osteotomies may be created with burs, saws or piezosurgery tips. The posterior vertical osteotomy is made through the outer cortex perpendicular to the external oblique ridge at the level of the occlusal plane, or at a point of adequate thickness. The anterior vertical osteotomy is also made through the outer cortex. The distance between the posterior and anterior cut is determined by the desired graft length and may extend as far forward as the distal aspect of the first molar tooth. The height of these cuts corresponds to the height of the desired graft. The posterior and anterior osteotomies are then connected superiorly with a horizontal osteotomy 3–4 mm in depth. The depth of all these cuts is monocortical. The inferior connecting cuts are made with a no. 8 round bur or an angled piezosurgery tip. The inferior cut simply scores the cortex, enabling fracture along this line during subsequent luxation of the graft with osteotomes. Thin osteotomes are used to complete the osteotomies staying along the buccal cortical plate so as to avoid potential injury to the inferior alveolar nerve. Larger osteotomes are then used to free the block of bone (Figure 11.4). The surgeon should ensure that the inferior alveolar nerve is not tethered to the graft prior to removal. The bed of the osteotomy is then inspected and the inferior alveolar nerve may be visualized. Small amounts of cancellous bone may be removed with curettes while being mindful of the location of the nerve. The donor site is then irrigated and closed using resorbable or non-resorbable suture with or without the use of haemostatic agents such as microfibrillar collagen soaked in thrombin. It is not usually necessary to graft the donor site since bony regeneration is adequate.

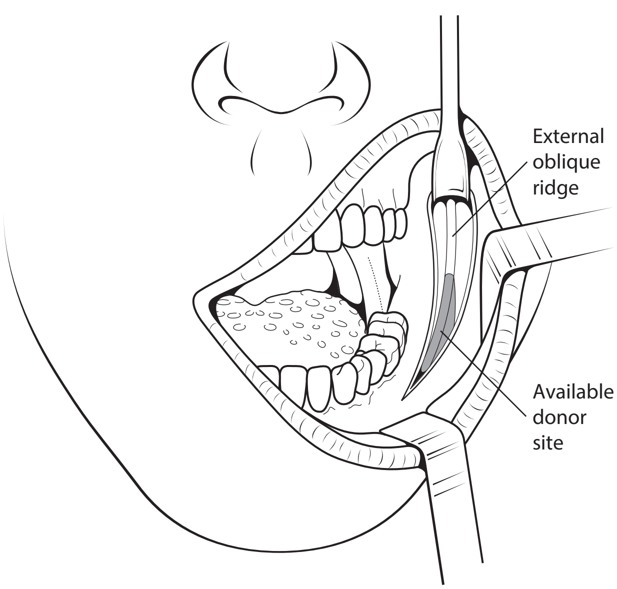

Figure 11.4 Mandibular ramus donor site.

Post-operative management

An elasticated jaw bra-type dressing may be applied and the patient instructed to apply ice to the area for 24 hours to reduce the swelling. Analgesics and post-operative antibiotics are prescribed and oral hygiene and diet recommendations are made.

Complications

The most common complications are hematoma, infection, wound dehiscence and inferior alveolar or lingual nerve injury. The incidence of sensory deficit following ramus harvest is reported to be lower than that at symphyseal harvest, at 8% and 16%, respectively. There is also the possibility of fracture during the procedure or in the post-operative healing phase.

Maxillary tuberosity and zygomatico-maxillary buttress

The volume of bone available from these sites is limited but may be mixed with allogenic material and/or supplements such as PRP or BMP (BMP-2 or BMP-7) for added volume. The pre-operative preparation and anaesthetic technique are similar to that used for the mandibular symphyseal and ramus donor sites. Once a standard mucoperiostial flap is elevated bone shavings can be harvested from these sites using shaving devices such as the MX-grafter, or using ronguers to remove bone from the tuberosity area taking care not to enter the maxillary antrum. There is also the option of removing a small and thin window of bone from the anterior maxillary wall in the buttress region. This window is typically only 2–3 mm thick and 1 cm × 1 cm in dimension.

RECIPIENT SITE TECHNIQUES

Onlay graft

Onlay grafts may be used to augment the width and/or the height of the alveolus, although vertical augmentation is challenging. Once the bone graft has been harvested it should be stored in saline and kept moist until the time of grafting. The success of onlay grafts relies on recipient bed vascularity, close approximation and contact between graft and the recipient site, and graft immobilization. In addition, there must be tension-free soft tissue closure over the site to minimize the risk of wound dehiscence, which may result in graft failure and loss.

The incision for the recipient site may be made at the crest of the ridge or in the vestibule. Incisions on the crest give easy access but they are often directly over the graft and are at risk of dehiscence with subsequent graft failure and loss. Incisions placed in the vestibule are away from the graft, but the flap relies on perfusion from the lingual or palatal side and is therefore at risk for breakdown, especially if the crest is composed of dense fibrous tissue.

The recipient bed should be prepared to allow close approximation between the recipient bed and the onlay graft, as well as improve immobilization of the graft. This is often achieved by reduction of convexities and mortising the bed to receive the graft. A small bur may be used to perforate the recipient site as well as the graft itself. The recipient site perforations are monocortical. This is performed to encourage early capillary ingrowth and vascularization (Figure 11.5). The block is then stabilized using one or two 1.2-mm diameter screws to avoid rotation (Figure 11.5). If greater width is desired than the thickness of the graft will allow, the graft may be placed as two layers, or secured using positioning screws leaving space under the graft that can be filled with cancellous bone or allogenic bone (Figure 11.6). Any sharp edges of the graft are smoothed to reduce the chance of mucosal breakdown. Cancellous bone or allogenic bone may be placed around the periphery to further augment the site and anticipate some post-operative resorption. This particulate bone graft may also be placed as an interpositional graft between the block graft and recipient site for contour discrepancies that may create unfavourable surgical dead space and soft tissue ingrowth. Membranes may be overlaid onto the graft although many surgeons feel that this increases the risk of wound dehiscence and infection. However if the periosteum is to be released and additional particulate bone graft is used around the margins of the block graft, a membrane should be considered. Loose and unstable particulate bone graft should not be introduced into tissue planes deep to the periosteum.

The soft tissue must be closed without tension. Prior to closure, the buccal periostium may be incised and undermined to allow advancement of the flap. The incision is closed using non-resorbable sutures. Analgesics and post-operative antibiotics are prescribed and oral hygiene and diet recommendations are made. The grafted site should be allowed to heal and consolidate for 4–6 months prior to implant placement.

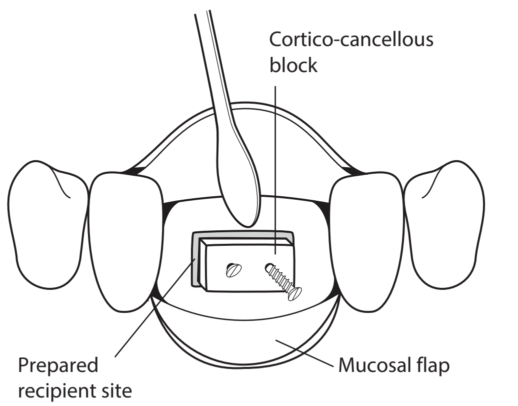

Figure 11.5 Mortised onlay graft.

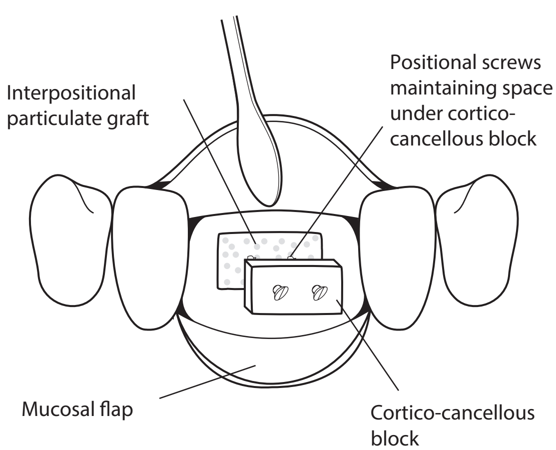

Figure 11.6 Onlay graft.

Maxillary sinus grafting

Maxillary sinus grafting was first described in the 1970s and its success has improved. The alveolus in the edentulous posterior maxilla is often occupied by a large pneumatized maxillary antrum, resulting in vertical bone deficiency. Grafting the floor of the sinus increases the vertical dimension of bone available for successful implant placement. Until recently, this has been performed with simultaneous placement of the implants if there was at least 5 mm of native bone height to provide primary stability for the implant, but if there was less than 5 mm of bone height, implant placement was deferred to a second procedure 4–6 months following the sinus graft. However, recent literature reports successful implant placement in as little as 1 mm of native bone height, provided there is adequate width (8 mm or more). In these situations, some surgeons will use corticocancellous blocks mortised into the floor of the sinus to provide more stability for the implants.

Pre-operative preparation

Panoramic radiographs are adequate to assess the vertical height of bone available at the implant site, but CT scans provide more detailed three-dimensional topographic visualization of the sinus floor and surrounding walls, including the presence of septae within the sinus. In addition, CT scans allow visualization of the sinus mucosa. Patients with sinusitis or sinus disease should be referred for appropriate management before grafting. Local mouth preparation should include chlorhexidine mouth rinse pre-operatively and many surgeons use a perioperative antibiotic that is administered either enterally or parenterally before surgery.

Procedure

Access to the sinus is performed through a Caldwell Luc window in the lateral wall of the sinus. The initial mucosal incision may be placed in the vestibule although this may increase the likelihood of oro-antral fistula formation in the event of wound dehiscence. This may be avoided by utilizing a crestal or sulcular incision away from the bony window. Once a full thickness mucoperiostial flap is elevated and the lateral wall of the maxilla and sinus is exposed, a 1 cm × 1.5 cm bony window is created anterior to the zygomaticomaxillary buttress (Figure 11.7). The superior osteotomy is placed inferior to the infraorbital nerve at the level of the planned graft height, while the inferior osteotomy should lie approximately 3 mm above the floor of the sinus so as to avoid the multiple septations and recesses often encountered along the sinus floor, which make completing the osteotomy and infracturing the bony window problematic. Occasionally, a second window is needed if there is a septum within the sinus. The bony window is created using a diamond bur or a piezosurgery tip to minimize the chance of Schneiderian membrane perforation. Small perforations (<3 mm) are inconsequential, but larger perforations should be covered with a resorbable membrane after elevation of the lining and prior to insertion of the graft. Once the bony widow is created and the sinus lining is visible around the periphery, sinus curettes are used to carefully mobilize and elevate the Schneiderian membrane with the cortical window still attached. Once mobilized, the membrane and bony window is turned into the sinus such that the bony segment now becomes the new elevated sinus floor. The space beneath the elevated bony segment and the lining is filled with bone or substitute graft material (Figure 11.7). The volume of the graft placed should allow for 20% resorption prior to implant placement. The average volume of graft material required to augment the sinus is 5 mL. Autogenous bone remains the gold standard graft material, but this may be mixed with or even substituted with allogenic bone with good success. Recent literature also reports good success with collagen soaked in BMP (BMP-2 or BMP-7).

To close the site, a resorbable membrane is placed over the bony window and the mucoperiostial flap is sutured with non-resorbable sutures which are left in place for 2 weeks.

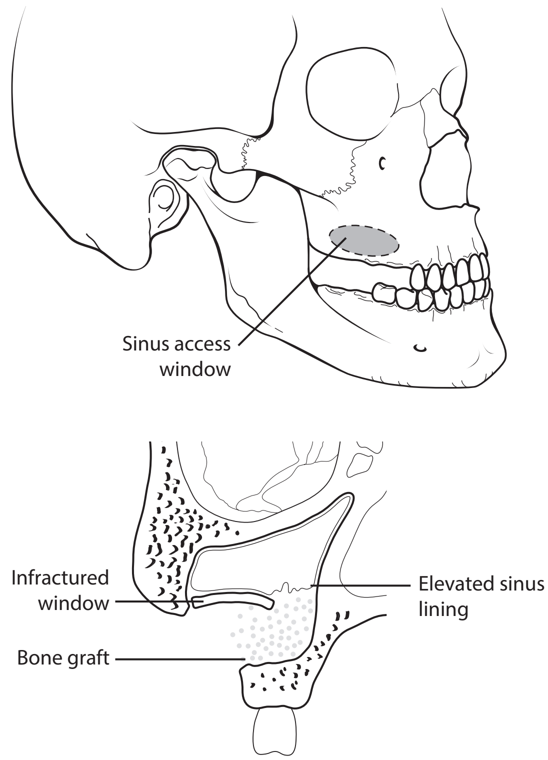

Figure 11.7 Sinus lift/augmentation.

Post-operative management

In addition to the usual post-operative management of intraoral graft sites as, the patient should be instructed in sinus precautions. These are especially important if the sinus lining was perforated, and should include no nose blowing or sucking through straws for at least 3 weeks. Nasal decongestants and saline nasal spray may also be helpful.

Complications

Potential complications include infection, acute maxillary sinusitis, wound breakdown and subsequent failure of the graft, injury to the infraorbital nerve, injury to adjacent tooth roots with devitalization and oro-antral fistula.

Alveolar bone splitting/spreading

Osteotomies along the alveolar crest may be performed in the maxilla and the mandible in order to increase the width of the alveolus (Figure 11.8). The pre-operative preparation is the same as other grafting procedure, however, the flap dissection is different. To maintain blood supply to the osteotomized inner and outer segments, the periostium is left attached to the bone. This is achieved by a crestal or vestibular incision, and a supraperiostial dissection of the labial or buccal mucosal flap. The crestal osteotomy may be made with a saw, a small fissure bur or a piezosurgery tip. The vertical osteotomies may be carried through both inner and outer cortical plates if expansion of both plates is desired. Alternatively, the vertical cut may be through only the buccal/labial cortex if lingual expansion is not required. The vertical osteotomies are usually 1 cm in height. Once the osteotomies are made, osteotomes are driven into the crestal cut and the cortical plate(s) are pedicled on the overlying periostium. The intervening space may then be implanted or grafted with bone or substitute graft materials. The segments and intervening graft may be stabilized using miniplates or screws for immobilization during the healing phase. In addition, many

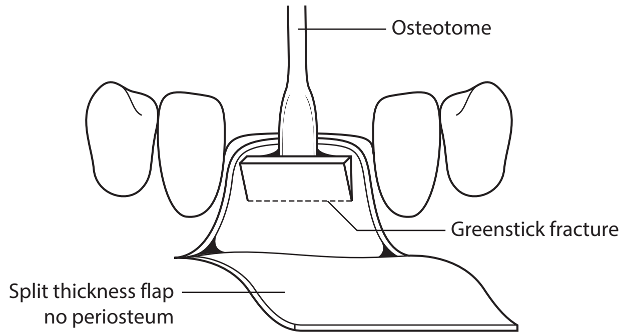

Figure 11.8 Alveolar ridge splitting.

surgeons will cover the site with a resorbable membrane prior to suturing with a non-resorbable suture.

Bone regeneration

Recombinant human bone morphogenetic protein-2 or acellular collagen sponge (rhBMP-2/ACS) has proven to be osteoinductive for several orthopedic surgical procedures. Application to oral implantology includes horizontal and vertical maxillary alveolar ridge augmentation and sinus augmentation. rhBMP-2/ACS has chemoattractants for stem cells and osteoprogenitor cells, serving as a source of bone-forming cells. Studies have described the successful use of additional materials in combination with rhBMP-2/ACS as a composite graft, such as crushed cancellous freeze-dried allogeneic bone (CCFDAB), and PRP. The graft material is then contained in a titanium mesh crib, which is later removed as a second stage surgery. The ACS gradually resorbs and the occupied space is replaced by regenerated bone. Recipient sites are generally ready for implantation in 4–6 months.

Procedure

A chlorohexidine rinse is used and a local anaesthetic with vasoconstrictor is applied to the surgical area. The incision for the recipient site may be made at the crest of the ridge with releasing incisions. Full-thickness mucoperiosteal flaps are elevated to expose the atrophic alveolar ridge. rhBMP-2/ACS is prepared according to the manufacturer's instructions: for example the ACS may be soak-loaded with reconstituted rhBMP-2 and allowed to rest for 15 minutes prior to graft delivery (Figure 11.9). Buccal decortication or monocortical bur perforations of the buccal cortex may be performed to prepare the recipient site prior to graft implantation. The prepared grafting material may be delivered in a space-maintaining titanium mesh crib, 0.2 mm in thickness. The titanium mesh is contoured to the desired height and width augmentation and the arch form as well. Graft material is compressed to fill the titanium mesh and the mesh is secured to the alveolar bone using titanium screws (Figure 11.9). The mesh should be non-mobile after implantation. Alternate methods of space maintenance without using a titanium mesh crib have been described: bone block fixation screws may be inserted into the alveolar ridge with the screw heads positioned approximately 4 mm from the crest. At this point, the graft material is compressed around the screws until it extends above the screw heads, taking care not to cover the screw heads. In all methods, it is important to achieve a tension-free primary closure above the titanium mesh and graft material. Further release of periosteum and advancement of the mucoperiosteum may be necessary to achieve primary closure. The flap is sutured closed with non-resorbable sutures.

Post-operative management

Analgesics and post-operative antibiotics are prescribed and oral hygiene and diet recommendations are made.

Complications

In addition to complications discussed in previous sections, there may be resorption and loss of the alveolar segment. Mobility of the titanium mesh or screws may cause infection and ultimately lead to graft failure and loss. One of the most frequent complications is wound dehiscence and subsequent exposure of the hardware. This may be managed conservatively with hygiene and observation, or may require surgical closure of the wound. There is always a risk of inflammatory or foreign body reaction to hardware placement.

Transalveolar osteotome sinus lift

In patients with a residual bone height of at least 5 mm, augmentation of the sinus floor can be accomplished via a transalveolar approach using the osteotome technique. This technique may be used at the time of implant placement. The main indication for osteotome sinus floor elevation is vertical bone deficiency. This procedure is designed to increase the density and height of bone. Using the elasticity of soft maxillary bone, dilation and elevation of the sinus floor can be achieved, thus increasing the length of implants. Adjacent bone is compressed by mallet tapping as the sinus membrane is elevated. Additional graft material may be added to increase the volume below the elevated sinus membrane. Local contraindications include inadequate bone height (<5 mm) and width allowing for primary stability of an implant and oblique sinus floor (>45° inclination) due to the increased risk of perforation of the Schnederian membrane. The sinus floor may be elevated up to 5 mm without perforation of the sinus membrane. Specific relative contraindications include patients with a history of inner ear complications, positional vertigo and smoking.

Procedure

A chlorohexidine rinse is used and local anaesthetic with vasoconstrictor is applied to the area of interest. If this procedure is performed at the time of immediate implant placement, standard procedures apply to atraumatic

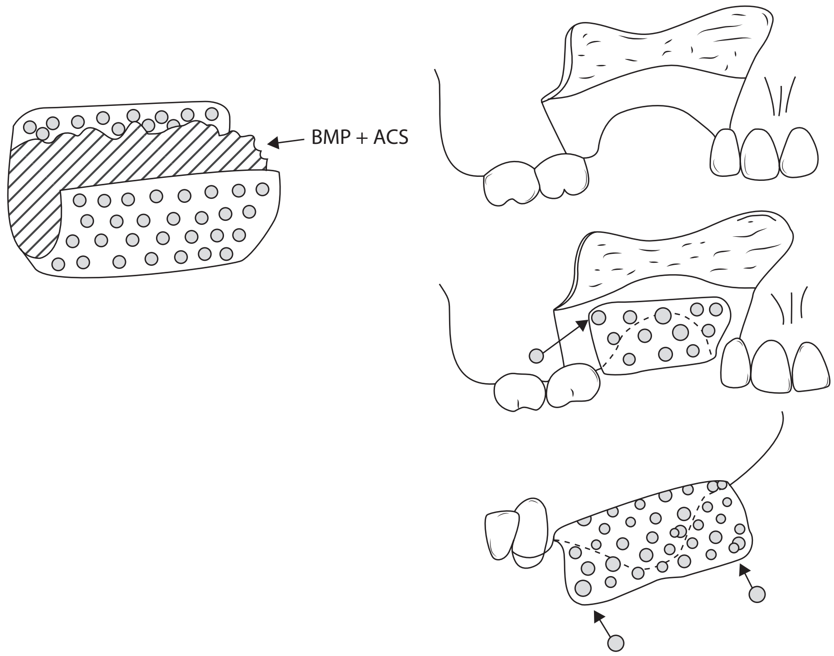

Figure 11.9 Screw retained titanium mesh loaded with bone morphogenetic protein (BMP) on alveolar crest. ACS, acellular collagen sponge.

tooth extraction and site debridement and preparation. If this procedure is not performed for immediate implant placement, a mid-crestal incision may be made with or without vertical releasing incisions. A full thickness mucoperiosteal flap is then raised for site exposure. Small diameter pilot drills and implant drills are used to prepare the implant site. It is important to underprepare the implant site by 0.5–1 mm smaller than the intended implant width. The implant site should be prepared with careful consideration to avoid perforation of the sinus floor. 2 mm of bone should remain between the most apical extent of site preparation and the maxillary sinus floor (Figure 11.10). At this point, a tapered osteotome with a concave cup-ended tip is applied vertically into the implant site and used to create a greenstick fracture of the maxillary sinus and push the sinus floor apically, increasing the length of the implant preparation (Figure 11.10). The concave and cutting edge of the osteotome tip will both harvest bone from the adjacent walls and compress the bone in an apical direction. The mallet force should be carefully controlled to prevent membrane perforation. A second tapered osteotome with a larger diameter than the first is used to increase both the width and vertical height of the osteotomy. Round-tipped osteotomes may be used as depth guides between osteotomies to confirm the preparation height. The last osteotome used should be 0.5 mm less than the implant width. The intrusion and elevation of the sinus floor and membrane will create a tent and potential dead space beneath the sinus membrane and bony sinus floor. At this point the sinus membrane may be lifted beyond the margins of the osteotomy through transalveolar access with a series of curved curettes which are found in comercially available sinus manipulation kits. After instrumentation of the membrane superiorly additional space is created in order to place particulate bone graft. Many surgeons will not perform further internal sinus membrane manipulation once the desired height of implant is achieved by intrusion alone. Implant placement may then be performed with or without additional grafting material (Figure 11.10).

Post-operative management

Post-operative management is the same as maxillary sinus grafting.

Complications

Potential complications are similar to maxillary sinus grafting. Sinus perforation is the main intraoperative complication, which may be confirmed by direct instrumentation and/or a Valsalva manoeuvre, visualizing a bubble or leak from the osteotomy site. Excessive force or bone trauma may affect primary stability of the implant and also cause resorption of bone. Benign paroxysmal positional vertigo has been described but is uncommon.

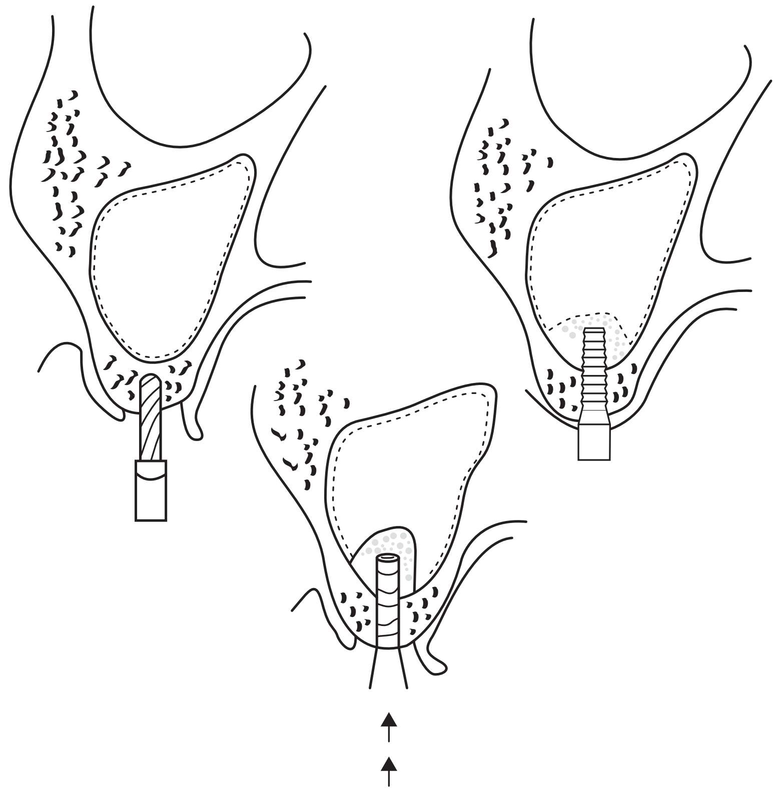

Figure 11.10 Transalvoelar osteotome sinus lift.

Top tips

- Autogenous bone is considered the gold standard due to its osteoblastic, osteoinductive and osteoconductive properties.
- Potential bone yields from various donor sites: mandibular symphysis = 5 mL, mandibular ramus = 5–10 mL, proximal tibia = 20–40 mL, anterior iliac crest = 50 mL and posterior iliac crest =50–100 mL.
- Membranous bone grafts show less rapid resorption than endochondral bone grafts.
- Cancellous grafts vascularize more rapidly than corticocancellous grafts.
- The mandibular symphysis provides blocks of corticocancellous bone measuring up to 1.5–2 cm in length, 1 cm in height and 4–7 mm in thick.
- The mandibular ramus provides corticocancellous blocks of bone measuring up to 3 cm in length, 1 cm in height and 4 mm thick.
- Implants may be placed simultaneously with open sinus floor augmentation if there is 5 mm or more of native bone height, although recent literature shows success in as little as 1 mm of native bone height, if there is adequate width.
- Implant length may be heightened with the use of the transalveolar osteotome sinus lift. Preparation for implantation should be approximately 2 mm from the sinus floor prior to intrusion.

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12

Basic and advanced implantology – A European perspective

JOHN CAWOOD and MOHAN FRANCIS PATEL

CONTENTS

The introduction and development of endosteal implants have brought about a revolution in that implant-supported prosthetic devices have become the state of the art.

Nowadays, the establishment and maintenance of osseointegration are very predictable if the relevant factors are taken into consideration such as favourable anatomical form and environment, biocompatibility and favourable long-term biomechanical conditions. Advances in implant design and surface modification such as anodic oxidation, encourage direct bone formation onto the implant surface, thus increasing initial implant stability and improving outcome.

At present, the level of evidence indicative of absolute and relative contraindications for implant treatment due to systemic disease is low. Similarly, the evidence base remains weak with regard to pre-existing periodontal disease. Studies at the patient level suggest survival of implants and superstructure is not significantly different from non-periodontally compromised patients. However, at the implant level, the incidence of peri-implantitis and marginal bone loss is significantly increased in the periodontally compromised patient. It should be noted that no study has documented that the survival of an implant exceeds that of a tooth properly treated for periodontitis.

The success rate for immediate loading of implants varies between 80% and 100% after 1 year with higher success rates recorded in the mandible than the maxilla. Survival of conventionally loaded implants is reported as 98% after 1 year.

In bone graft patients, studies show increased bone contact with implants and increased implant stability when implant placement is delayed for at least 3 months to allow revascularization of the graft, new bone formation and remodelling of the bone graft.

Advances in both surgical technology and surgical techniques have increased the predictability of pre-implant surgery and have also reduced the morbidity of such surgery. Technological advances include improved imaging techniques, dedicated instrumentation, bone plates and screws and development of biomaterials such as bone substitutes and membranes for guided tissue regeneration. Computerized tomography (CT) allows accurate measurements to be made and provides information on bone density. Interactive planning has refined treatment

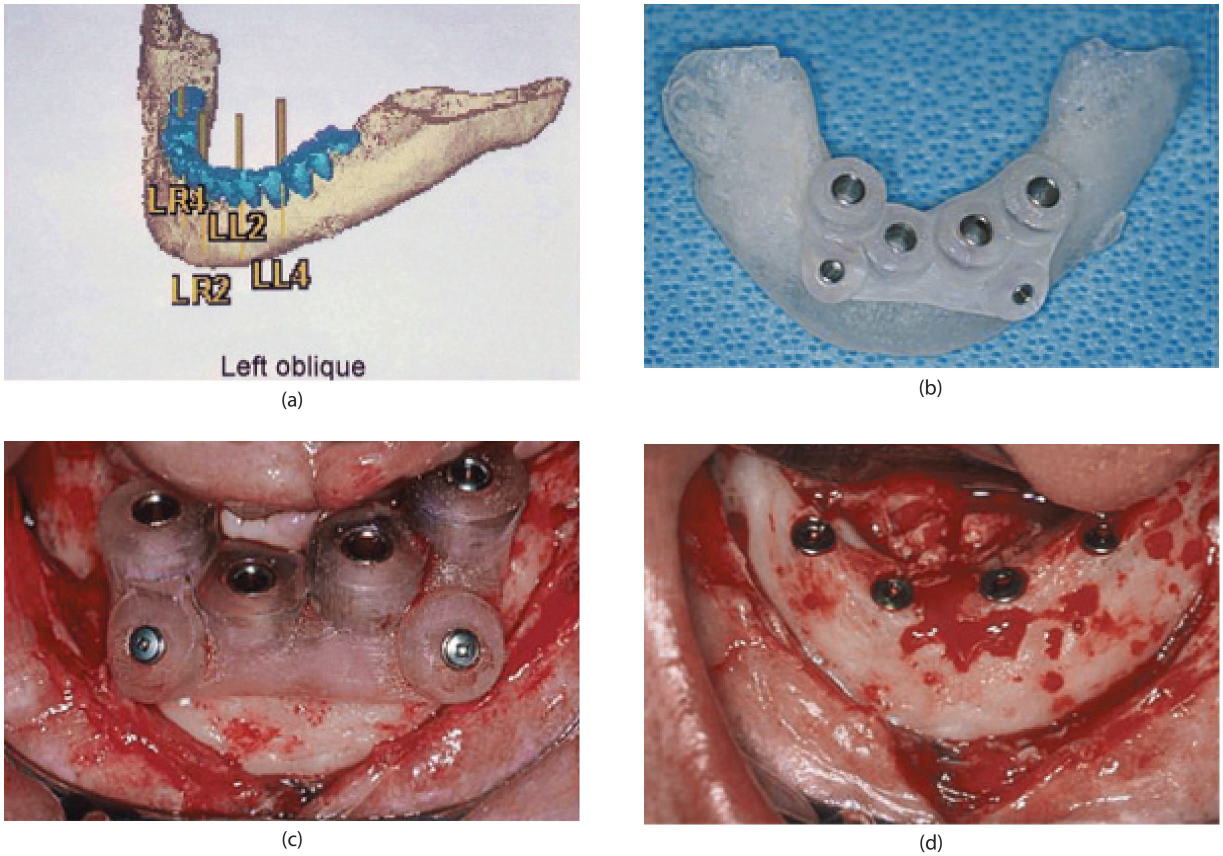

Figure 12.1 Computer-generated steriolithographic model and surgical guide for control of implant placement. (a) Stereolithographic model of mandible. (b) Computer-generated surgical guide for implant placement. (c) Surgical guide in situ and position secured with screws. (d) Implants in situ.

planning and treatment execution. Computer-generated models (stereolithography) allow for simulated surgery and provision of templates – further increasing the predictability of the treatment outcome (Figure 12.1).

PRE-IMPLANT SURGERY

Following tooth loss, there is loss of alveolar bone due to disuse atrophy. At first, bone loss is rapid. After 2–3 years, the rate diminishes but loss does continue indefinitely (Figure 12.2). There is an associated decrease in mucosal coverage of both the keratinized and non-keratinized mucosa which quickly compromises the potential implant site.

Pre-implant surgery is intended not only to improve the implant site per se but also to correct deficiencies in height and width of the alveolus and to restore or improve the intermaxillary relationship. This is because loss of bone in the edentulous jaw, and to a lesser extent in the partially edentulous jaw, leads to an alteration of the maxillo-mandibular jaw relationship, encroachment of muscle attachments in relation to the edentulous alveolus and a decrease in the surface area of the overlying mucosa. The effect of these changes combined with ageing, circumoral hypotonia and collapse results in changes of facial form and appearance (Figure 12.3).

There must be adequate bone volume both in height and width to allow placement of implants of sufficiently large dimensions to withstand functional loading and permit optimal axial inclination in order to fulfil the functional and aesthetic requirements without interfering with adjacent anatomical structures – for example, the neurovascular bundle, maxillary sinus and adjacent teeth. Vertical transverse and antero-posterior intermaxillary relationships should be favourable. If the foregoing conditions do not prevail, pre-implant surgery – including bone augmentation, soft-tissue procedures and possibly an osteotomy – may be undertaken.

Based on the Cawood and Howell classification of the edentulous jaws, a scheme for pre-implant surgery has evolved (Figure 12.4).

- *Class I*: dentate
- *Class II*: post-extraction
- *Class III*: adequate height and width
- *Class IV*: adequate height, inadequate width ('knife-edge ridge')
- *Class V*: inadequate height, inadequate width ('flat ridge')
- *Class VI*: loss of basal bone ('submerged ridge')

In a study of 300 edentulous patients by Longman, the type of jaw atrophy was assessed. The most frequently

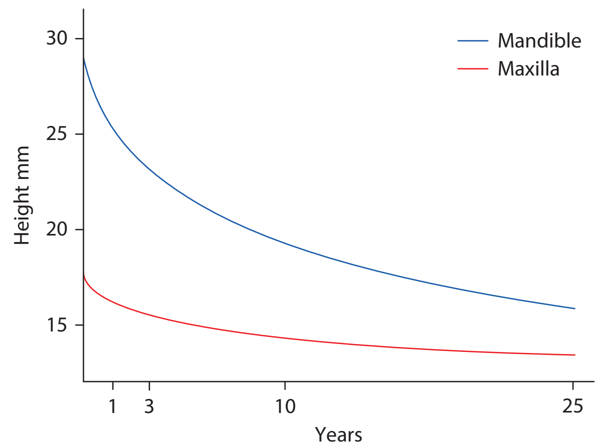

Figure 12.2 Reduction of ridge height of the edentulous mandible and maxilla over time. (Adapted from Tallgren A, *J Prosthet Dent*, 1972, Feb;27(2):120–32.)

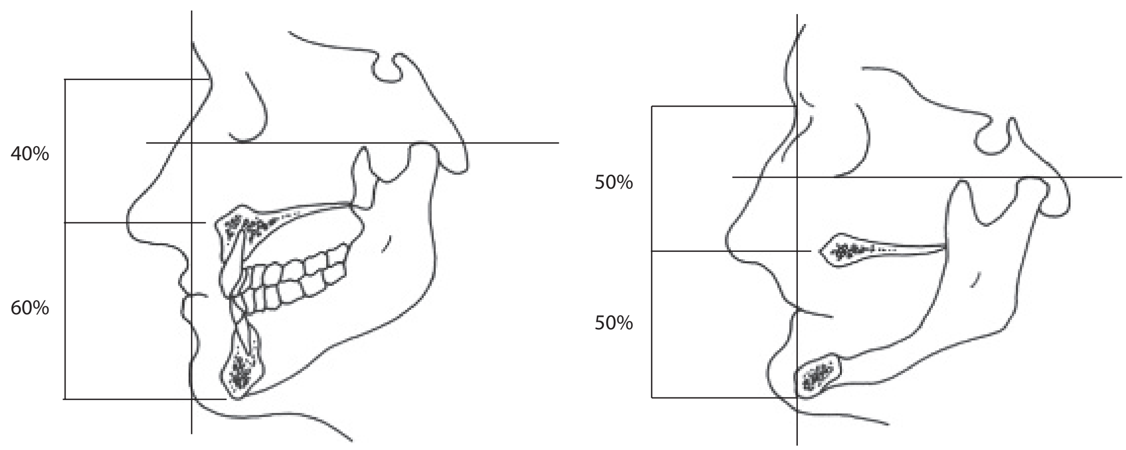

Figure 12.3 Consequences of jaw atrophy. Decreased lower face height, prognathism and collapse of lower facial soft tissue are shown.

encountered pattern of jaw atrophy is Class IV in the maxilla and Class V in the mandible (Figure 12.4).

In the Class IV, V and VI edentulous or partially dentate jaws, implant placement is usually combined with bone augmentation using onlay grafts, inlay grafts and/or interpositional grafts and in addition soft-tissue procedures.

The choice of bone graft is influenced by the type of grafts required, i.e. block graft or particulate graft. The quantity of bone required will determine the donor site, i.e. local (intra-oral) or distant (e.g. iliac crest). Corticocancellous block grafts are used to augment areas where there are deficiencies in width and height of the alveolar process. Particulate grafts are used to fill two- or three-walled defects, e.g. augmentation of the floor of the maxillary sinus or interpositional bone grafts.

There is a fundamental difference in the healing of these grafts which should be taken into account when using them. Unlike block corticocancellous bone grafts, most of the particulate cancellous bone graft is able to survive with areas of new bone formation occurring throughout the original graft. Even when dehiscence occurs, usually only a small portion of the particulate graft is lost. The primary healing depends on capillary ingrowth, not only from the bone surface of the recipient site but also from the enveloping soft tissue. Particulate grafts are difficult to use as onlay grafts because containment is a problem. The use of barrier membranes is useful when small alveolar defects have to be filled.

Corticocancellous block grafts provide a scaffold that will be resorbed almost completely to be replaced by new bone by the process of creeping bone substitution. Rigid fixation of corticocancellous grafts to the recipient site is essential for this proves to take place unhindered. Any micro-movement at the interface between the graft and recipient site will jeopardize capillary ingrowth from the recipient bed, resulting in avascular necrosis and loss of the graft. It is always advisable to use at least two screws to fix the bone to prevent any micro-movement. Other important factors are the close adaptation of the graft itself to the recipient bed and tension-free closure of the soft tissue. Depending on the size of the graft, revascularization will occur in approximately 2 weeks; subsequently remodelling begins. It is therefore advisable to delay insertions of endosteal implants for at least 3 months following placement of the bone graft.

SOFT-TISSUE PROCEDURES

The main objective of soft-tissue procedures is to improve the peri-implant environment in order to eliminate mobile mucosa or inflammatory hyperplasia. Ideally, implants should be surrounded by an immobile keratinized mucosa. For this reason, split-thickness mucosal grafts are harvested from the palate in strips, using a mucotome, which are draped around the implants and secured with a dressing plate (Figure 12.5).

Connective tissue grafts are usually harvested from the palate to correct mucogingival defects around implants and also to augment residual small volume soft-tissue defects, mainly in the aesthetic zone (Figure 12.6). Small rotational flaps aid the envelopment of implants with keratinized mucosa and to restore the shape of the inter-dental papilla. The lip-switch technique, first described by Kazanjian, is indicated in those patients who have a shallow buccal vestibule in the mandibular vestibular area or a high attachment of the mentalis muscle to give a deepened sulcus.

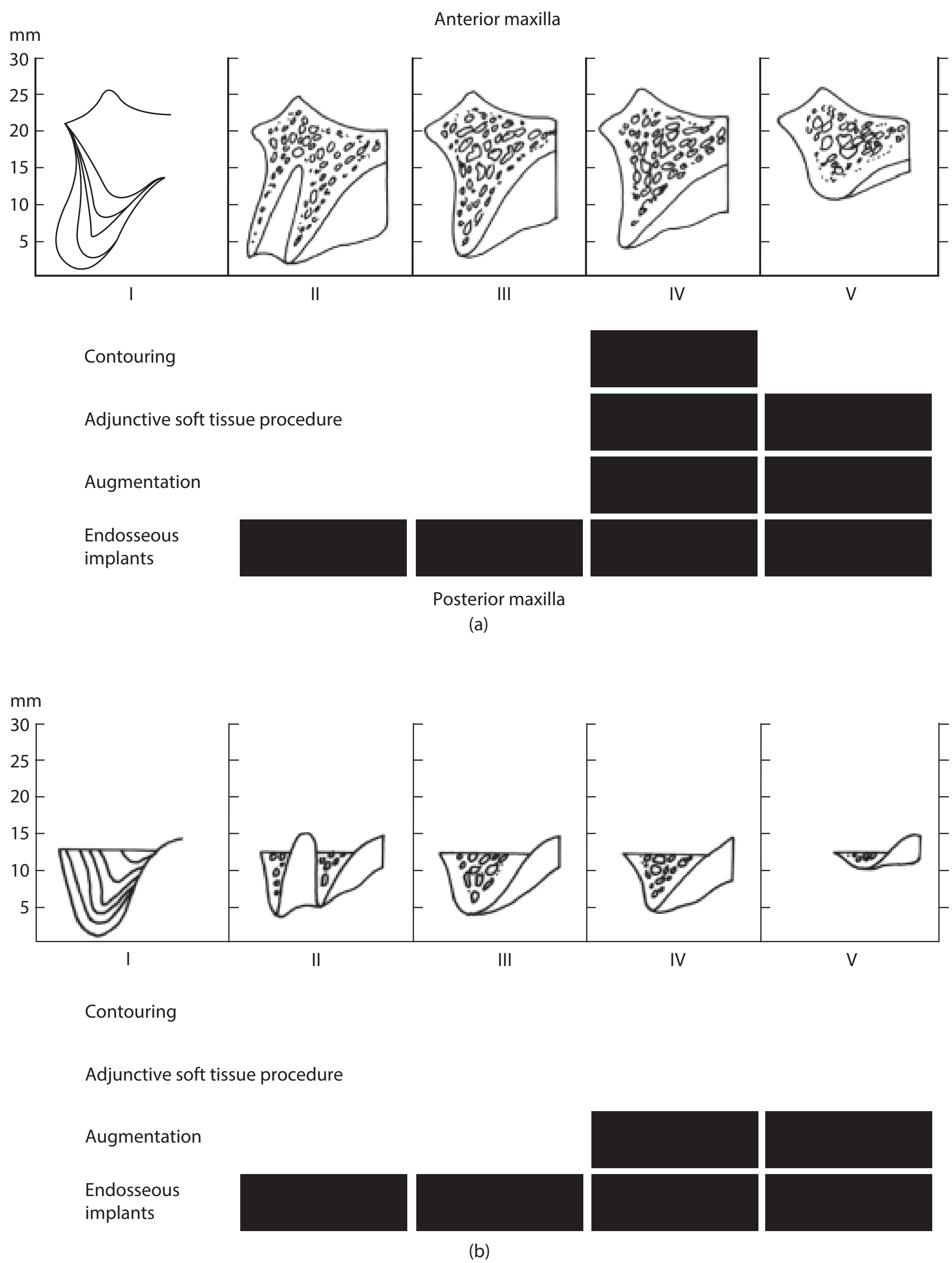

Figure 12.4 Scheme for pre-implant surgery based on Cawood and Howell classification of the edentulous jaw. (a) Anterior maxilla. (b) Posterior maxilla. (c) Anterior mandible. (d) Posterior mandible. (*Continued*)

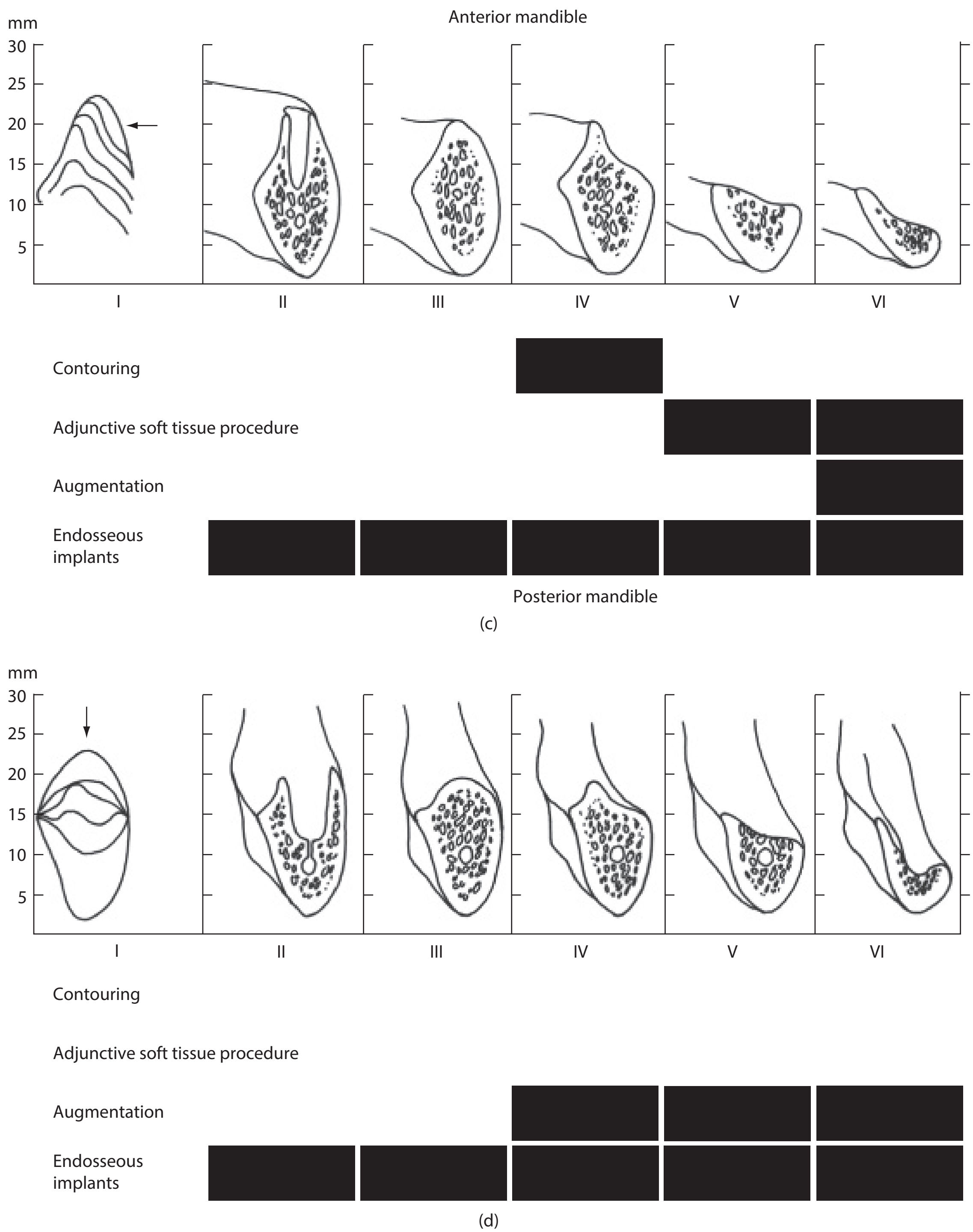

Figure 12.4 (*Continued*) Scheme for pre-implant surgery based on Cawood and Howell classification of the edentulous jaw. (a) Anterior maxilla. (b) Posterior maxilla. (c) Anterior mandible. (d) Posterior mandible.

CLASS II

Immediate placement of implants in extraction socket has the advantage of reducing the number of surgical interventions and reducing the time to delivery of the prosthesis.

- Use of periotome and sectioning of roots to preserve the integrity of the alveolar walls.
- Complete removal of the periodontal ligament, any granulation tissue and fibrous connective tissue.
- Acute and sub-acute periapical or periodontal infection is a contraindication to immediate implant placement.
- Engage bone beyond the socket to ensure initial implant stability.
- Coronal aspect of implant should be placed 2 mm apical to the coronal aspect of the socket to allow for bone remodelling and osseous regeneration.

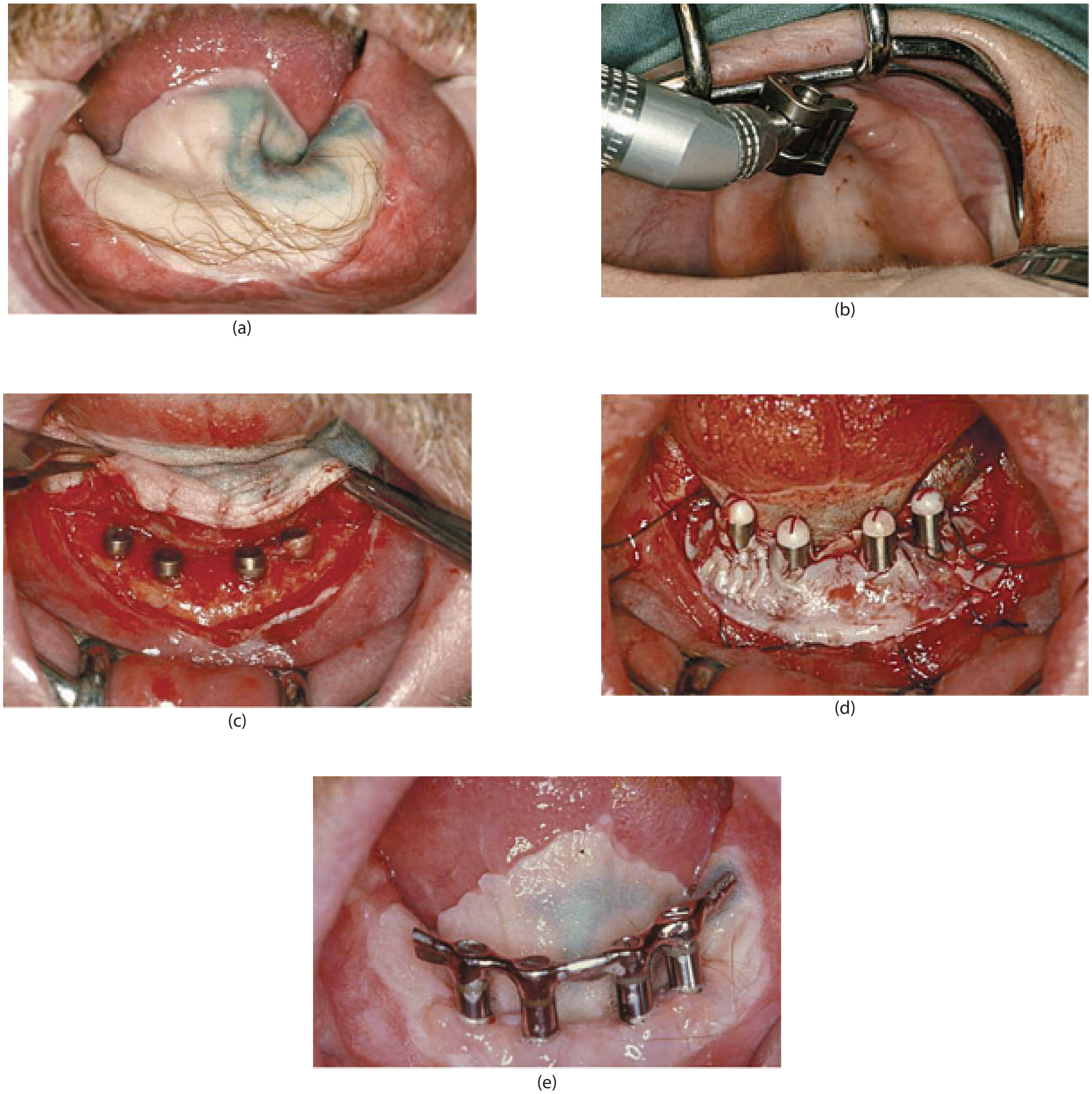

Figure 12.5 Split thickness mucosal graft to enhance implant environment, anterior floor of mouth. (a) Fasciocutaneous free flap anterior floor of mouth and rim resection surgery. (b) Harvesting mucosal graft from palate using a mucotome. (c) Alveolar ridge exposed and implants positioned. (d) Mucosal graft draped around implants. (e) Healed mucosal graft and implant superstructure.

- Small alveolar defects may be repaired by placement of a barrier membrane over augmentation material, provided soft-tissue coverage is possible.

Placement of an immediate implant is contraindicated where a defect of the coronal aspect of the socket exists. Instead allow complete healing of the socket. After 3 months, the residual alveolus can be repaired with an onlay graft (Figure 12.7).

CLASS III

Delayed implant placement in mature bone is a safe and predictable procedure. Immediate loading is possible provided there is a minimum height of 12 mm and a minimum width of 6 mm of alveolar bone. However, in the aesthetic zone the soft tissue should be level with the papilla of the adjacent teeth, otherwise augmentation is required. For delayed implant loading, a remote incision is preferred to reduce the risk of implant dehiscence. For immediate implant loading, a crestal incision is required. A surgical guide is essential for optimal site selection for implant placement and prosthetic outcome.

The direction of the implant bed is determined by the adjacent teeth and the direction of the cortical plates. Implant positioning should be no less than 2 mm from the adjacent teeth and no less than 3 mm from an adjacent implant. The pilot bur establishes the direction and

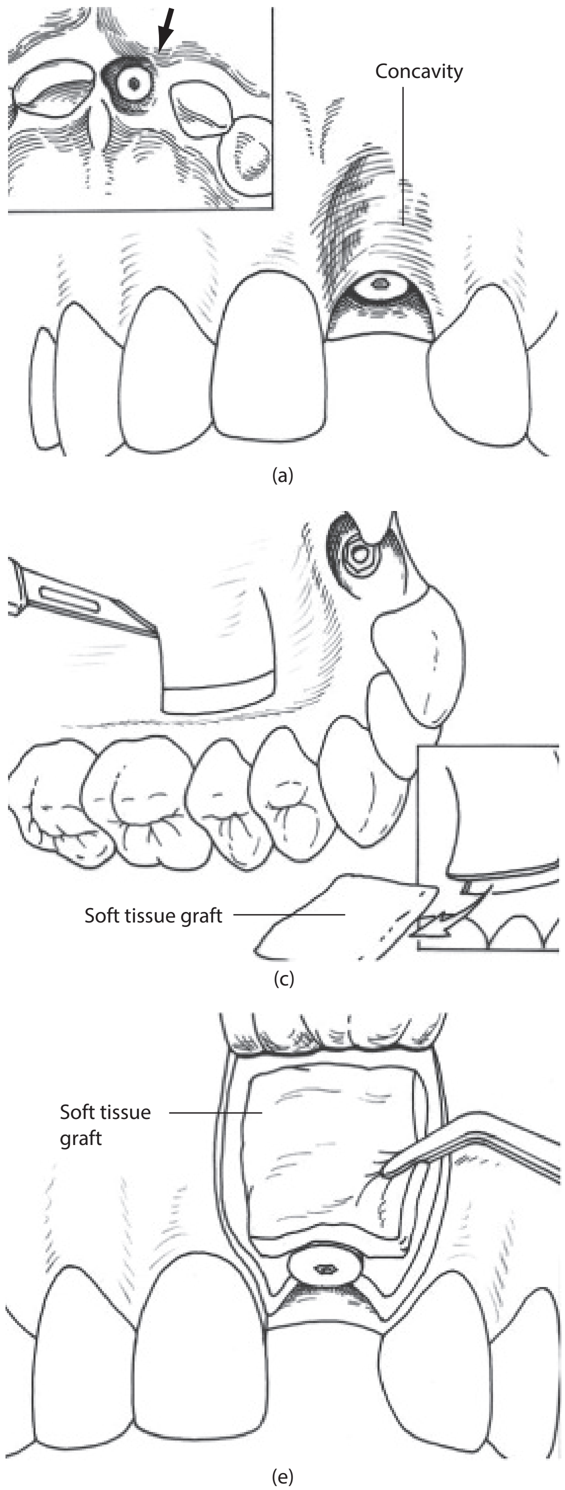

Figure 12.6 Soft-tissue management in implant placement. Connective tissue graft. (a) Concavity over implant site. (b) Elliptical incision on labial aspect. (c) Connective tissue graft harvested from palate. (d) Palatal flap sutured back. (e) Connective tissue graft placed over defect. (f) Flap replaced over connective tissue graft restoring contour.

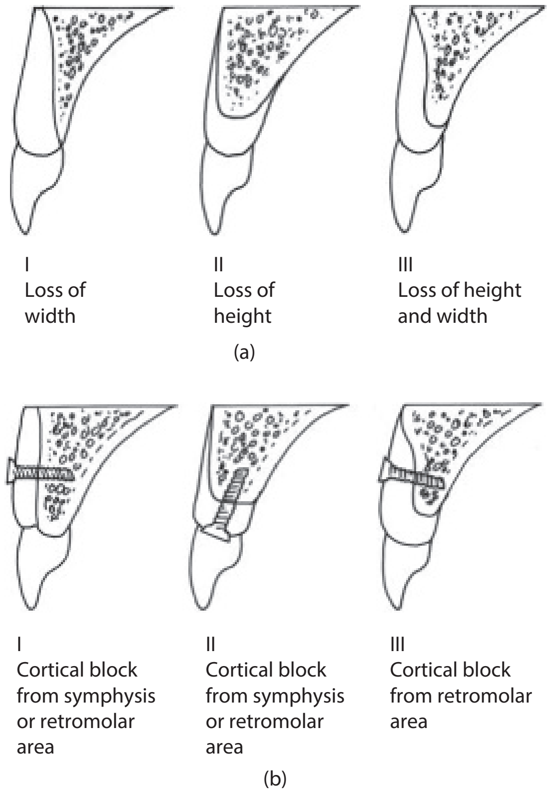

Figure 12.7 (a) Alveolar local bone deficiencies: I, loss of width; II, loss of height; III, loss of height and width. (b) Correction of local alveolar deficiency with locally harvested block grafts: I, Veneer graft; II, Onlay graft; III, Saddle graft. (Courtesy of Dr A. Sethi.)

depth of the implant bed. The diameter of the osteotomy is sequentially enlarged using graduated burs with copious irrigation to avoid thermal trauma to the bone. In low-density bone, the use of bone condensers is preferred to enlarge the osteotomy site which also compacts adjacent bone and aids primary implant stability. In high-density bone, the implants bed must be completely formed using hand reamers and bone taps. The implant bed depth should be 1 mm greater than the implant length.

CLASS IV (BONE EXPANSION)

- Bone expansion is indicated when the residual alveolar height is no less than 12 mm and the nasolabial support is adequate.
- Bone expansion should be carried out in a healed site with mature cortical plate.
- There should be intervening cancellous bone and no fusing of the cortical plates – a CT scan is helpful for this assessment.
- In the aesthetic zone, the overlying soft tissue should be level with the papillae of the adjacent teeth.
- CT scan should have reference radio-opaque markers so that the tooth position can be assessed in relation to the future implant position and indicates that the outcome is feasible.
- Surgical guide required to control implant position.
- Osteotomy is initiated with a scalpel blade.
- Expander is inserted into the cancellous bone between the cortical plates.
- Progressive dilation of implant bed to required dimension.
- Two-stage implant system advised.
- Healing period of 6 months.

CLASS IV MAXILLA (INADEQUATE NASOLABIAL SUPPORT)

In the anterior maxilla, the direction of bone loss is horizontal initially. This converts the broad Class III ridge into a narrow knife-edge ridge which had adequate height but inadequate width of residual bone to accommodate implants. The anterior maxillary osteotomy is designed to increase the width of the alveolus in order to insert implants and also to provide nasolabial support (Figure 12.8).

A CT scan is required to demonstrate that intervening cancellous bone is present and that there is no fusion of the cortical plates.

- A horseshoe-shaped incision is made in the labial mucosa and a mucosal flap dissected to a point approximately 3 mm below the crest of the alveolar crest.
- The periosteum is incised and a full-thickness mucoperiosteal flap reflected onto the palatal aspect.
- A sagittal osteotomy is developed using a scalpel blade to penetrate the cancellous bone. The osteotomy is completed with a fine reciprocating saw. The cortical bone of the nasal floor is osteotomized with a fine osteotome. Vertical bone cuts are made through the buccal cortex in the premolar region.
- The anterior nasal spine is removed and the anterior part of the nasal septum is detached from the anterior segment to be mobilized.
- The labial segment is mobilized anteriorly approximately 6 mm and stabilized with either microplates or position screws.
- An interpositional graft of particulate bone is inserted.
- Tension-free closure of the mucosa is obtained.
- Implants placed after 3 months.
- The anterior maxillary osteoplasty can be combined with sinus floor augmentation (Figure 12.8).

Where there is fusion of the cortical plates, augmentation of the Class IV ridge is achieved using a block veneer graft which is stabilized with lag screws.

For single tooth replacement in the anterior maxilla, augmentation of the alveolus is required for optimal implant placement and soft-tissue support using a veneer graft harvested from the mandible.

- Remote palatal incision extended within the crevicular margin labially to involve one unit either side of the recipient site. Papilla sparing incisions and bevelled incisions optimize the aesthetic result.

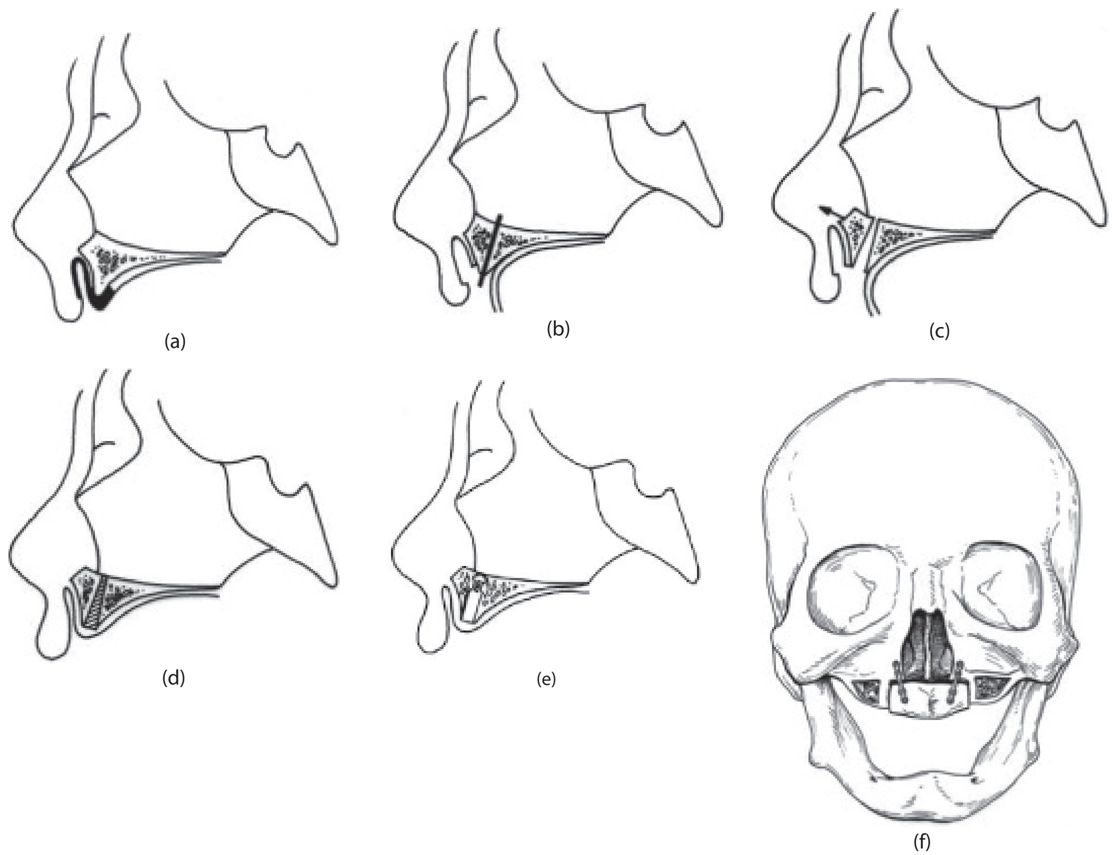

Figure 12.8 Anterior maxillary osteoplasty to broaden the narrow maxillary ridge. (a) Flap design (shaded area). Labial incision, submucosal dissection deepened to full thickness over crest of ridge. (b) Contouring of crestal irregularities (shaded). Vertical osteotomy cut extending into the nasal floor. (c) Mobilization of anterior segment labially. (d) Placement of interpositional bone graft (shaded). (e) Placement of endosseous implants following incorporation of bone graft. (f) Anterior maxillary osteoplasty and sinus floor lift for implant placement in maxilla.

- Bone graft is contoured to fit the recipient site passively.
- Bone graft secured with two microscrews to avoid risk of micro-movement.
- Tension-free closure of mucosa is obtained using a periosteal release incision if necessary.
- Implant placement after 3 months.

Sufficient bone can be obtained from the mandibular ramus area for placement of up to four implants. An increase in width of 2–6 mm and an increase in height of about 4 mm can be achieved.

CLASS V MAXILLA

The Class V maxilla is characterized by loss of the alveolar process resulting in a vertical, transverse and antero-posterior alteration of the interarch relationship. Extensive augmentation with autogenous bone is required to restore the alveolar dimension and provide the necessary facial support. Bone is harvested from the iliac crest.

To determine the quantity of bone to be harvested, the selected tooth position is related to a stone cast of the edentulous ridge by means of a plater matrix. Silicone can be used to form a template to facilitate both the harvesting of bone from the iliac crest area and also to adapt the graft to the recipient site.

The onlay graft is stabilized using position screws. Tension-free closure is obligatory and is facilitated with a periosteal release incision. Implant placement should be delayed for at least 3 months.

CLASS VI MAXILLA

Resorption of the maxillary alveolar process eventually leads to a relatively posterior and cranial position of the maxilla resulting in a reversed intermaxillary relationship and increased vertical intermaxillary distance. Reconstruction of the Class VI maxilla aims at restoration of interarch relationship and augmentation of the alveolar bone to provide support for the collapsed facial musculature and implant placement.

SURGICAL TECHNIQUE

A horseshoe incision is made high in the vestibule from first molar to first molar. The mucoperiosteum is reflected and the lateral sinus wall and nasal aperture are exposed.

A No. 5 round bur is used to make the horizontal osteotomy cut. The thin sinus membrane is elevated (preferably intact). The bone cuts are completed including the medial sinus wall and nasal septum. The tuberosity is detached from the pterygoid plate using a small osteotome. Due to the fragile nature of the maxilla, the 'down fracture' procedure must be carried out gently. In cases of severe rupture of the sinus membrane, the exposed sinus is sealed with a cortical plate bone stabilized with a microplate. The mobilized maxilla is fixed in the planned position with four microplates. The intervening space is packed with particulate cancellous bone. Tension-free closure of the soft tissues is obligatory and periosteal release incision may be required for this to be achieved. Implants are placed at least 3 months later in the planned position using a surgical guide.

ATROPHIC MANDIBLE

Unlike the maxilla, which is composed of trabecular bone predominantly with a thin cortex, the mandible has a thick cortical layer. This provides superior support for endosteal implants particularly in the anterior mandible. Following tooth loss, the blood supply of the edentulous mandible differs from that of the dentate mandible. In the dentate mandible, blood supply is principally centrifugal, arising mainly from the inferior alveolar artery and periodontal arterial arcades. The blood supply of the edentulous mandible is mainly centripetal, being derived via the subperiosteal plexus. Therefore, when carrying out pre-implant surgery of the edentulous mandible elevation of the mucoperiosteum must be performed carefully to avoid damaging the periosteal layer and subsequent ischaemic necrosis of the underlying bone.

CLASS II AND III MANDIBLE

Similar to the maxilla endosteal implants can be inserted, minimal pre-implant surgery being required. However, it should be noted that any surgical interference with the inferior alveolar nerve may lead to sensory alteration and loss which can be permanent.

CLASS IV AND V MANDIBLE

In the Class IV anterior mandible, contouring to remove the narrow ridge or onlay bone grafting will be influenced by the prosthetic requirements. In the Class V edentulous mandible, anteriorly implants may be inserted without need for bone augmentation. However, the soft-tissue environment is unfavourable with reduced keratinized mucosa and a shallow sulcus. A Kazanjian flap is useful to increase the area of attached mucosa and at the same time deepen the labial sulcus.

CLASS VI MANDIBLE

The Class VI mandible is characterized by loss of basal bone that can be extensive. Often the inferior alveolar canal is exposed and pain results from compression of the nerve during function. Augmentation of the Class VI mandible is indicated when the residual height is less than 10 mm. Augmentation is accomplished either with an interpositional bone graft or an onlay bone graft. The choice between these two techniques is partly operator dependent and partly dependent on the relationship of the soft tissues of the floor of mouth relative to the residual ridge. If the lax tissues of the floor of mouth 'spill' over the residual ridge, then an onlay bone graft is more effective in 'damming back' the floor of mouth tissues. Via a subperiosteal tunnel, an onlay graft is placed in the posterior mandible to cover the exposed inferior alveolar canal. Implant placement is delayed for a minimum of 3 months.

Top tips

- CT or cone beam tomography aids planning and treatment.
- Use a surgical guide for implant placement.
- Consider bone augmentation for optimal implant placement.
- Autogenous bone remains the 'gold standard'.
- Rigid fixation of solid bone grafts is essential.
- Achieve tension-free closure of soft tissues.
- Keratinized mucosa should surround the implant.

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13

Major preprosthetic surgery, incorporating implants

EUGENE E KELLER

CONTENTS

MAXILLA (PARTIAL OR TOTAL EDENTULISM) RECONSTRUCTION

Introduction

Implant reconstruction of the severely resorbed edentulous maxilla frequently requires autogenous block bone graft reconstruction. This can be accomplished with iliac, cranial or mandibular corticocancellous block bone grafts. Depending on the degree of bone loss, the patient's functional or aesthetic requirements, and the prosthodontic requirements, the bone graft procedures can either be a one- or two-stage reconstruction. The one-stage reconstruction requires simultaneous placement of block bone grafts and endosseous root form dental implants. In the two-stage procedure, bone grafting and implant placement procedures are separated by 3–6 months to allow for bone graft healing. The bone grafting procedures are classified anatomically as onlay, inlay or interpositional types.

Onlay (one stage) corticocancellous block bone graft

Introduction

For totally edentulous patients with advanced bone loss, there also needs to be adequate bone quality and quantity between the anterior antral walls to accommodate four to six endosseous implants to stabilize the one-stage onlay bone graft. If there is insufficient bone, a two-stage onlay bone graft procedure is performed. In the latter situation, the bone graft is stabilized by miniplates or bone screws. There must also be adequate interarch space to accommodate the onlay bone graft and dental osseoprosthesis. The soft-tissue flap used to cover the onlay bone graft must be free of infection and significant scar tissue. A periosteal incision of the labial-buccal flap with mucosal advancement is needed for a critical watertight non-tension everted wound closure (Figure 13.1).

SURGICAL PROSTHETIC PROCEDURE

1. For full arch reconstruction, nasoendotracheal anaesthesia is required.
2. Labial-buccal incision position is critical.
3. Non-traumatic (low heat production) bone graft harvesting is critical to preserve cell viability of the cancellous and cambian layer of osteoblasts. Iliac bone is utilized for large full arch reconstruction and cranial or mandibular ramus or symphysis bone for smaller segmental reconstruction (see section 'Bone Graft Harvesting Techniques').
4. Rigid onlay bone graft stabilization (endosseous implants or miniplates and screws) is important to promote bone graft healing and simultaneous implant osseointegration (one-stage procedure).
5. Non-traumatic bone drilling osteotomy preparation prior to implant placement.

6. Non-tension everted watertight wound closure following periosteal incision.
7. Four to six months of minimal (physiologic) prosthesis loading.
8. Long-term physiologic dental prosthesis loading.

Inlay (antral and nasal) (one stage) corticocancellous block bone graft

Indications

This is indicated for totally edentulous patients with advanced bone resorption but inadequate interarch space to accommodate the onlay bone graft and associated osseoprosthesis. It is also indicated for patients with inadequate soft-tissue elasticity for onlay bone graft soft-tissue coverage. The surgeon can also elect to perform the inlay versus the onlay bone graft, bearing in mind that the final implant prosthesis will be affected (fixed-removable versus continuous fixed). For partially or totally edentulous patients, a two-stage bone grafting procedure can be performed utilizing either corticocancellous block or particulate bone grafts from the iliac crest, mandible or cranium. Various allogenic and autogenous bone particulate bone grafts can also be mixed to increase the particulate bone graft volume. This is not common in the author's practice as adequate volumes of cancellous bone can be harvested from the anterior and/or posterior iliac crest. If particulate bone grafts are utilized, the sinus membrane or various membranes (collagen preferred) need to be utilized to confine the graft material in the correct position for later secondary implant placement. If there is adequate sinus floor bone (5 mm or more), a one-stage procedure can be accomplished. However, in this situation, the author is frequently able to place short-wide diameter implants into the sinus floor without adjunctive bone grafting (Figure 13.2).

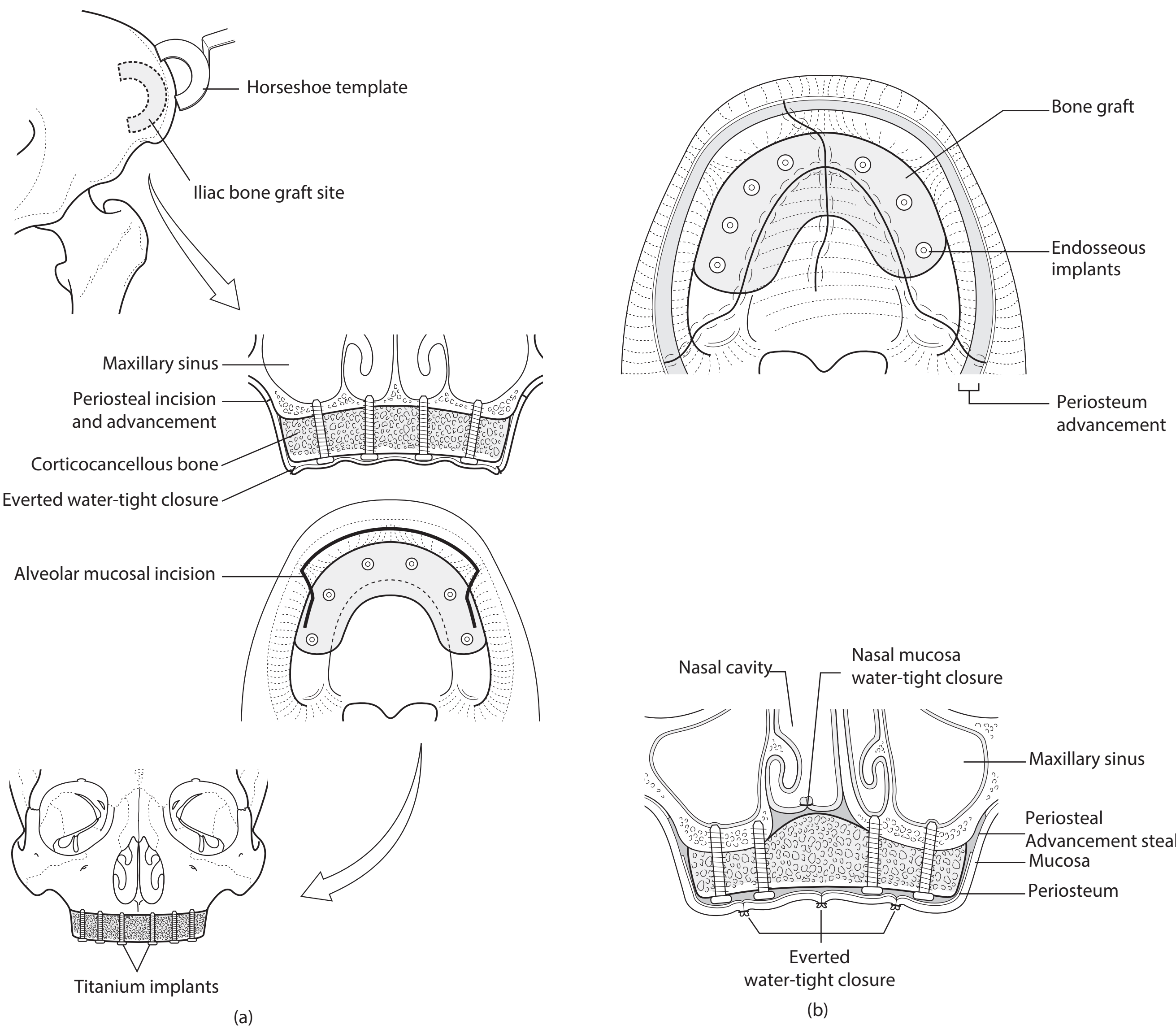


Figure 13.1 (a) and (b) Maxillary onlay (one stage) corticocancellous block iliac bone graft.

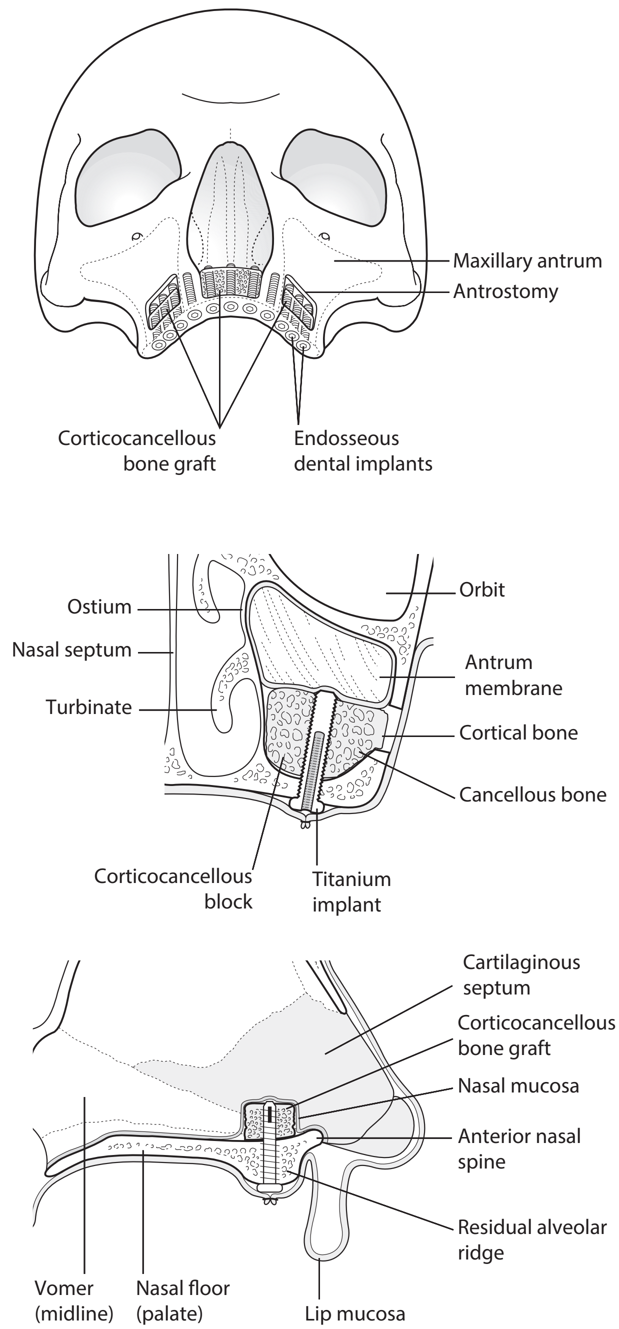


Figure 13.2 Maxillary nasal/antral inlay (one stage) corticocancellous block iliac bone graft.

Surgical procedure

1. Nasoendotracheal general anaesthesia is generally required for bilateral antral reconstruction in edentulous patients utilizing autogenous corticocancellous block bone grafts.
2. Crestal incisions are indicated to permit a periosteal releasing incision, limit sulcus scaring and allow periosteum coverage.
3. Rigid block bone graft stabilization (endosseous implant or miniplate and screws) is critical to enhance physiologic bone graft healing (revascularization, remineralization and transfer osteogenesis) to occur.
4. Non-tension watertight everted wound closure.
5. Four to six months of minimal (physiologic) bone graft and implant loading.
6. Long-term physiologic dental prosthesis loading.
7. Documentation of non-infected and properly ventilated antrum prior to antral floor reconstruction (preliminary antral procedures by appropriate surgeon may be indicated).

Interpositional corticocancellous block bone graft with Le Fort I down-graft osteotomy

Indications

This technique is indicated for partially or totally edentulous patients, who in addition to their edentulism exhibit two complicating factors: (1) horizontal and/or vertical maxillary deficiency with associated facial deformity and skeletal malocclusion and (2) inadequate bone quality and/or quantity to support endosseous implants in the edentulous area eventually requiring bone-anchored dental prosthesis. These patients are generally younger individuals, who have high functional and aesthetic expectations. They also frequently exhibit high functional disability in mastication, speech, deglutition and nasopharyngeal airflow (Figure 13.3).

Surgical procedure

1. This reconstructive effort is generally carried out in two stages: (1) the first involves a low Le Fort I osteotomy with correction of the vertical and/or horizontal skeletal deformity and malocclusion, and placement of interpositional block bone grafts to stabilize the repositioned maxilla and (2) provide bone volume and bone density for eventual endosseous implant reconstruction of the edentulous alveolar areas.
2. Adequate miniplate osteosynthesis stabilization of the repositioned maxilla and interpositional bone graft is critical for physiologic bone healing and maintenance of block bone graft volume for adequate numbers and adequate size of endosseous implant.
3. Antral floor membrane removal is important to ensure complete antral floor bone graft incorporation (antral graft for implants).
4. Particulate or block bone grafts across the down-fractured nasal floor is critical in patients missing anterior teeth and alveolar bone. This facilitates eventual endosseous implant reconstruction in this important aesthetic zone.
5. If the Le Fort I interpositional bone grafting is successful, the secondary implant reconstruction 4–6 months later requires routine implant surgical technique.
6. A one-stage procedure involving simultaneous osteotomy, autogenous bone grafting and endosseous implant reconstruction is technically difficult (requires both

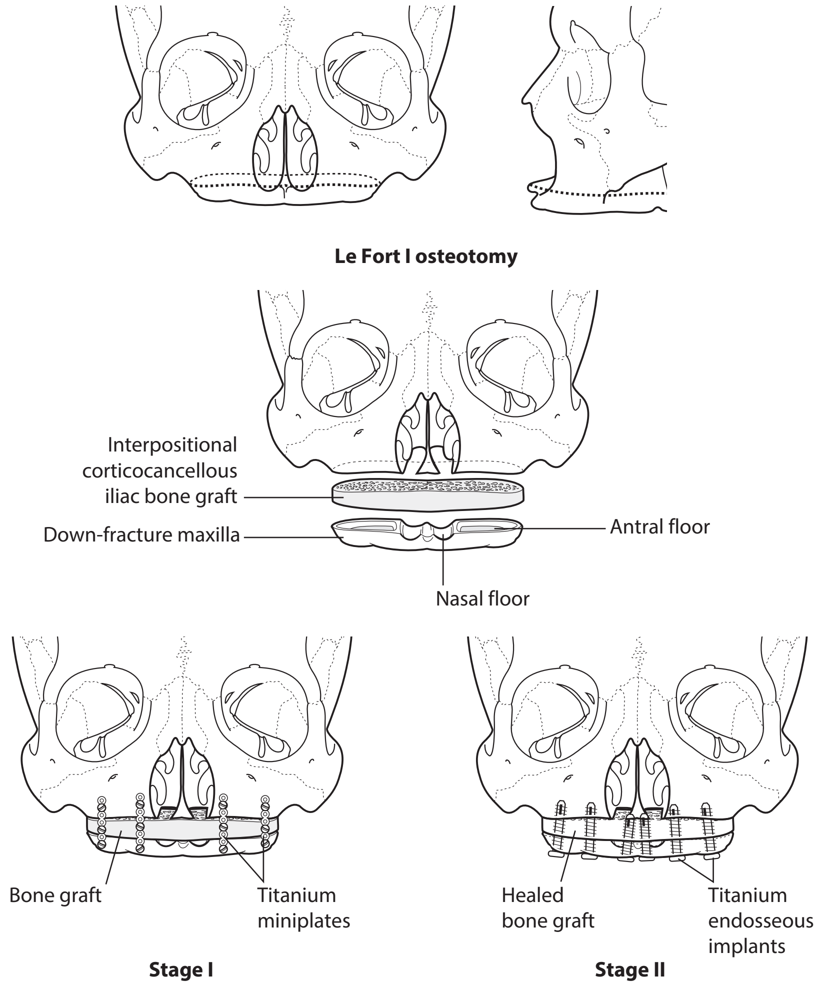


Figure 13.3 Interpositional corticocancellous block bone graft with Le Fort 1 down-graft osteotomy.

sulcus and alveolar ridge incisions) and may result in compromised implant position for final prosthesis fabrication. For these reasons, the one-stage versus two-stage procedure is rarely indicated.

MAXILLARY DISCONTINUITY RECONSTRUCTION

Indications

Segmental loss of alveolar and basal bone generally is secondary to congenital clefting or postsurgical/post-traumatic aetiology. The surgeon and prosthodontist need to decide whether bone grafting and implant reconstruction of the segmental defect is required, resulting in complete arch reconstruction with fixed or fixed/removable prosthesis, or whether an implant-supported removable obturator prosthesis is required. The size and aetiology of the discontinuity are an important consideration, as well as the patient's functional and aesthetic expectations. In general, the congenital clefts and small defects are bone grafted and secondarily reconstructed with a fixed implant prosthesis, whereas the large (hemimaxillectomy) defects are reconstructed with implant-supported removable obturator prosthesis. Vascularized composite (bone and soft tissue) is utilized in selected patients to reconstruct the large defects, thus avoiding an obturator removal prosthesis (Figure 13.4).

Surgical technique

1. Alveolar-palatal cleft (and smaller postoncologic or postsurgical defects) bone grafting needs to be accomplished in a manner where the osseous anatomy of the nasal floor, piriform aperture and anterior portion of the palate are fully reconstructed. In the author's hands, this requires a combination of corticocancellous block and cancellous particulate bone grafts from the iliac crest. In the growing cleft child, these bone grafts are placed between the ages of 7 and 10 years, when the cuspid roots is one-half to two-thirds formed, and

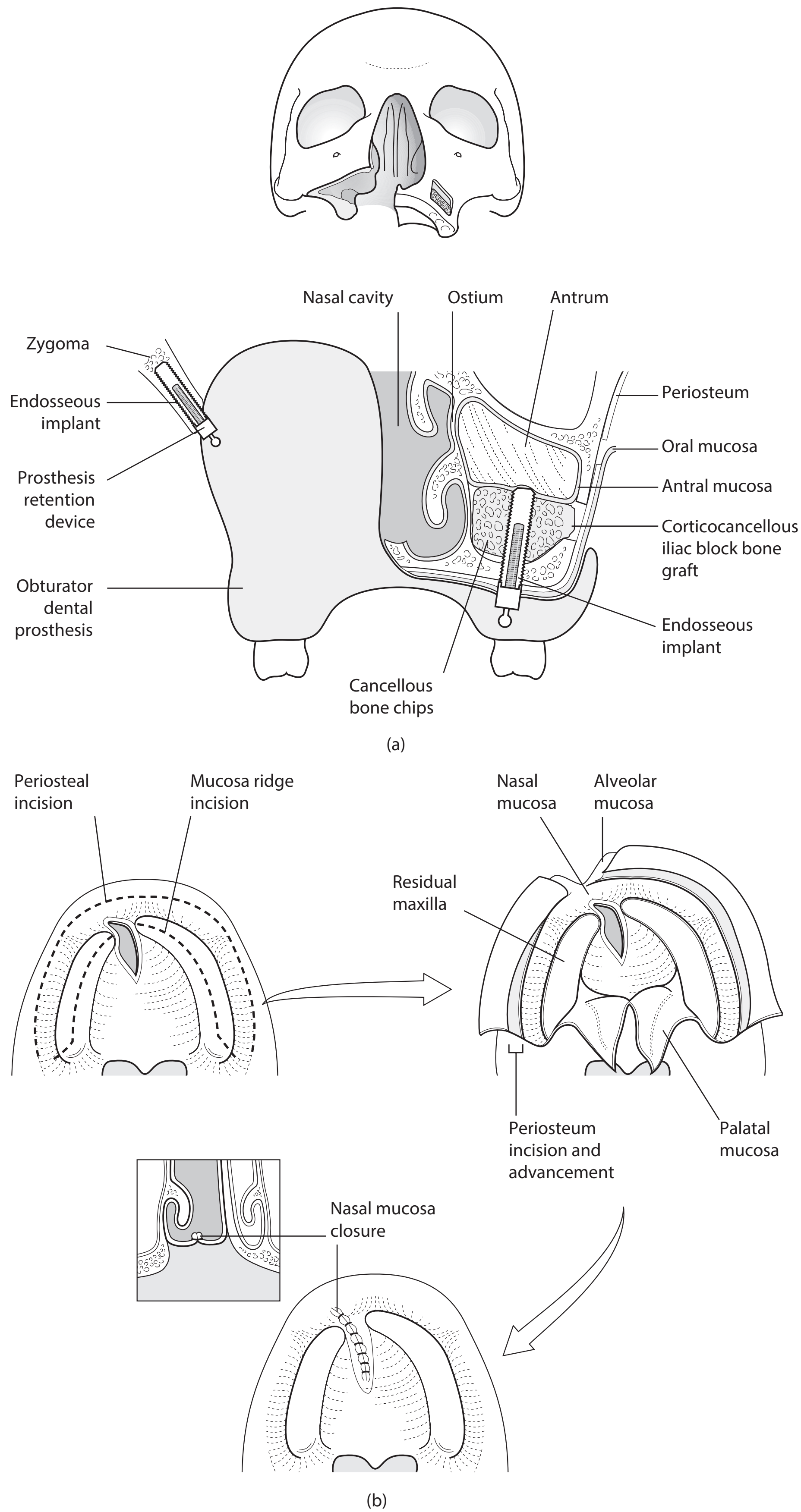


Figure 13.4 Maxillary discontinuity reconstruction with corticocancellous block iliac bone graft. (a) Hemimaxillectomy defect; (b) congenital alveolar/palatal defect.

in the adult, 4–6 months before endosseous implant placement; again, complete reconstruction of the missing anatomy is important, especially in the anterior aesthetic zone.
2. In larger postoncologic or post-traumatic defects (where non-vascularized bone grafts are contraindicated), the endosseous implants and/or onlay or inlay bone grafts are placed in the residual maxillary bone. The surgical techniques are the same as those described earlier (see under section 'Maxilla (Partial or Total Edentulism) Reconstruction'). This may be in the form of antral inlay or onlay bone grafts, or pterygoid and zygomatic implants. In this situation, the implant-supported prosthesis is a fixed-removable obturator type. More recently, vascularized composite bone grafts have been utilized for the larger defects. In this situation, it is important to have adequate volume and position of the bone graft; also, the soft-tissue portion frequently needs to be debulked to accommodate the dental prosthesis.

MANDIBLE (PARTIAL OR TOTAL EDENTULISM) RECONSTRUCTION

Implant reconstruction of advanced bone resorption without bone grafting

Indications

Patients with bone height equal to or greater than 5 mm and bone width equal to or greater than 7 mm between the mental foramen are candidates for placement of four or five endosseous implants (Figure 13.5).

Surgical technique

Because of the advanced bone resorption, a number of important surgical technique modifications are required:

(1) Crestal rather than sulcus incisions, to preserve the mentalis integrity; (2) conservative periosteal elevation to preserve a compromised (totally periosteal) blood supply to the residual mandible; (3) isolation of the bilateral mental nerve, which is positioned on the crest of the residual alveolar ridge; (4) low speed-high cooling bone cutting of dense hypovascular bone; (5) bone cutting threading of all osteotomy implant sites through the inferior border; (6) no implant osteotomy site bone bevelling; (7) placement of autogenous osseous coagulum obtained from taping the instrument through the implant preparation site to the inferior border; (8) place the endosseous implant at right angle to the occlusal plane; (9) avoid straight line placement of the anterior implant to avoid unfavourable cantilever prosthesis loading (at times, this will require uncovering of the thin bone overlying the inferior alveolar nerve and distalizing of the nerve to allow more posterior positioning of the right and left distal implant); (10) allow implant access holes to exit anterior to the dentition to counteract the dental class III occlusion tendency; (11) accept a high incidence of non-keratinized peri-implant tissue; (12) understand gradual physiologic increase of bilateral mandibular body height and width following functional prosthetic loading of the anterior mandible (Wolff's law of bone physiology).

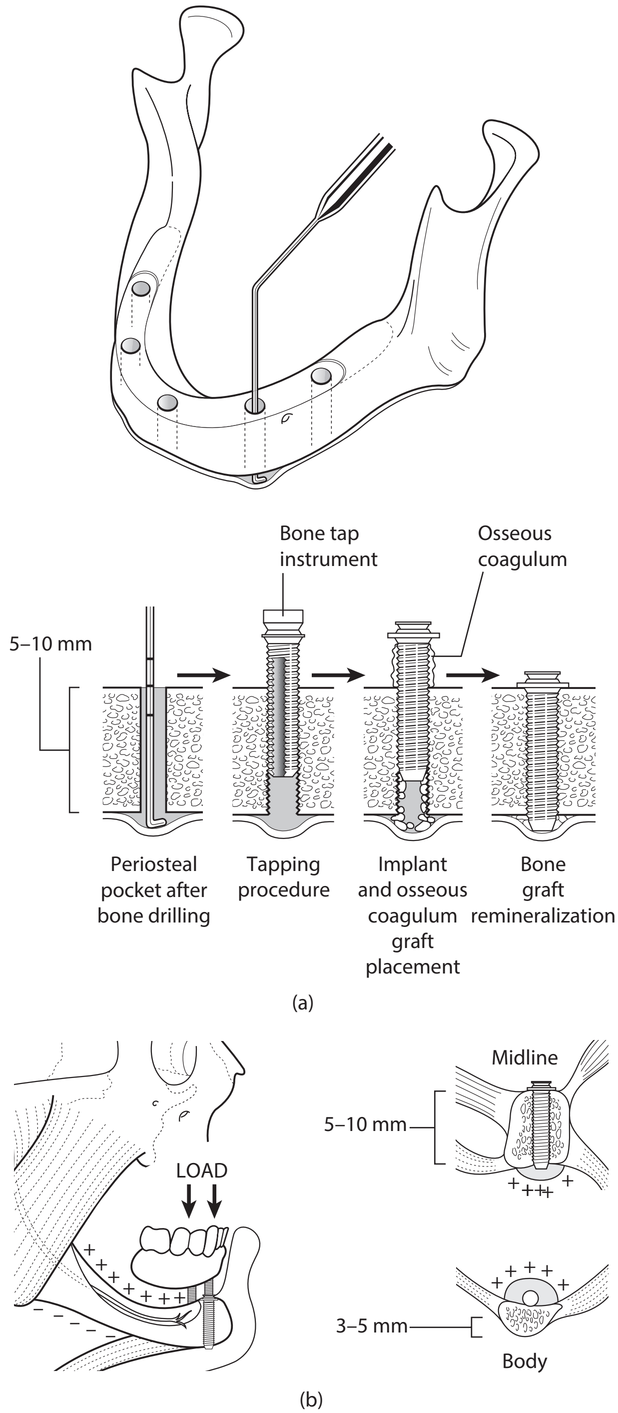


Figure 13.5 Mandibular endosseous implant reconstruction. (a) Advanced bone resorption; (b) functional bone remodelling after implant loading (Wolff's law).

Onlay corticocancellous block bone graft reconstruction of advance mandibular resorption

Indications

Adjunctive onlay bone grafting in the advanced bone resorption patient is required when the anterior residual bone is less than 5 mm in height and/or the width is less than 7 mm in the future endosseous implant sites. This group of patients can also avoid the onlay bone grafting procedure if they are willing to function with an overdenture-type prosthesis on two or three midline implants, where there is invariably enough bone (genial tubercle and mentalis muscle attachment area) for implant stability. In this situation, the patient would be willing to accept varying degrees of aesthetic and/or functional compromise (lower lip support and tooth position) (Figure 13.6).

Surgical technique

In addition to the surgical techniques aforementioned under implant reconstruction of advanced bone resorption without bone grafting.

1. Avoid transecting the mentalis muscle and conservative periosteum reflection.
2. Atraumatic bone grafting harvesting and atraumatic recipient site surgery bone healing (bone conduction, bone induction and transfer osteogenesis).
3. Provide watertight, everted tension-free wound closure to ensure early fluid nutrition and revascularization of the bone graft. This requires mobilization of the sublingual mucosa which is always highly redundant from previous bone loss.
4. Delayed placement (second stage) of the more posterior implant may be necessary due to the narrow width (<6 mm) in the mental foramen area. In this situation, the corticocancellous block bone graft may need further stabilization with miniplates or screws. The same situation exists when a unilateral posterior onlay bone graft is placed above the inferior alveolar nerve.
5. Delayed (2–3 weeks) placement of the interim prosthesis to avoid disturbing wound closure and to avoid early bone graft loading.
6. Bone graft placement does not extend more than 1 cm beyond most distal implants as this distal body bone will eventually regenerate in height and width after a period of time (1–3 years) of functional loading (Wolff's law of bone repose to physiologic loading tension in the bilateral body portion of the mandible, see Figure 13.5b).

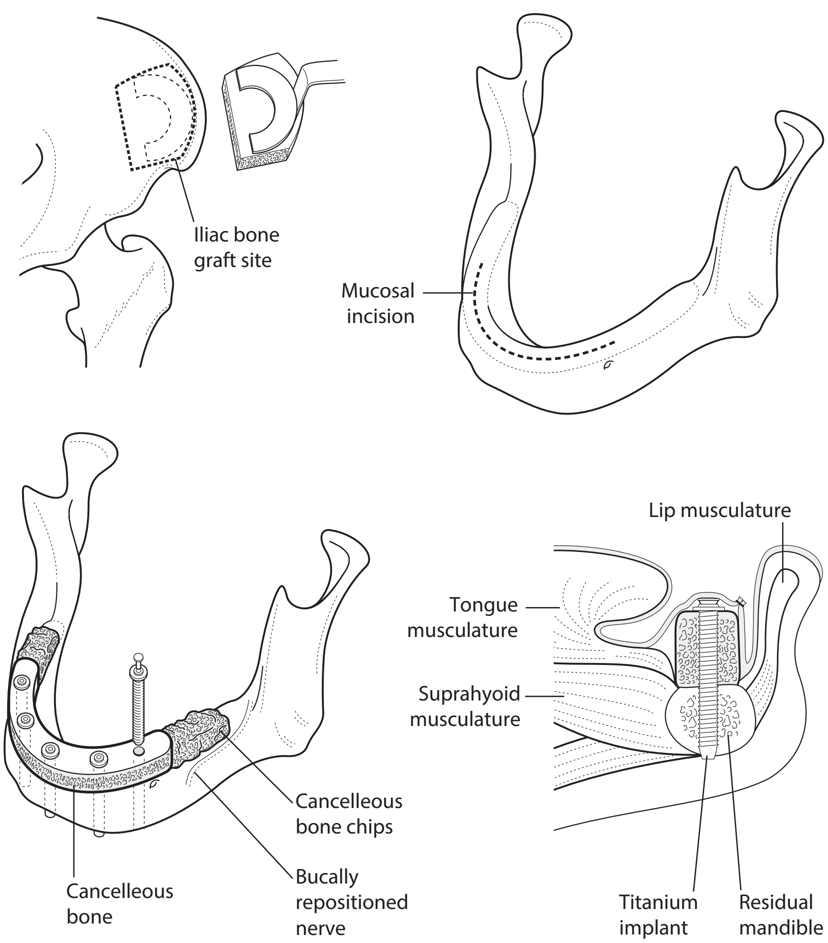


Figure 13.6 Mandibular onlay (one stage) corticocancellous block iliac bone graft.

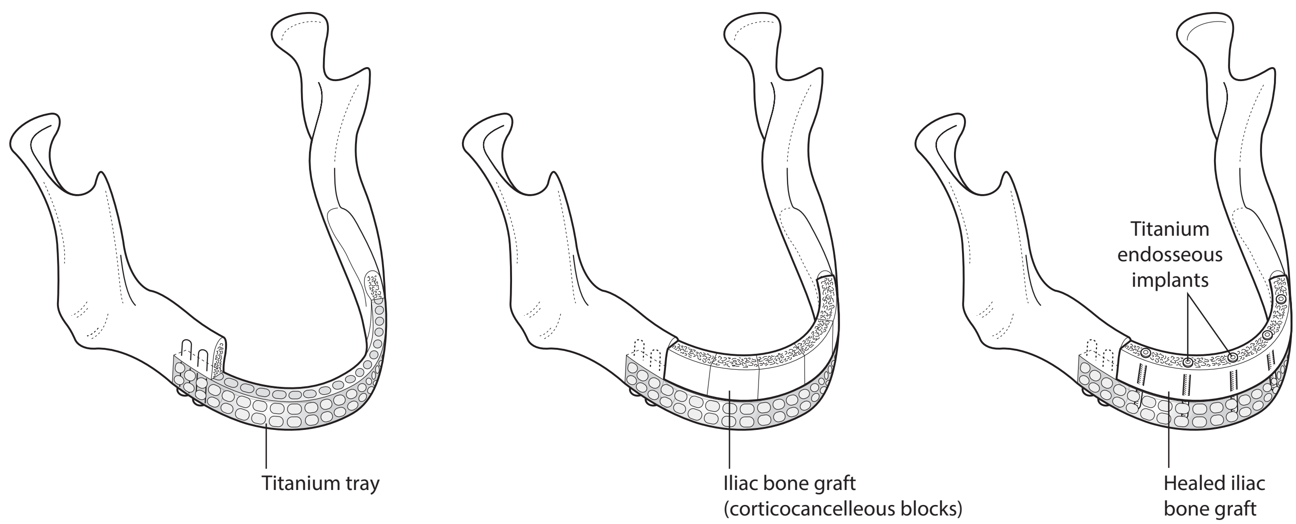
Discontinuity reconstruction with vascularized or non-vascularized block bone grafts and endosseous implants (two-stage procedure)

Indications

When mandibular discontinuity occurs following trauma, infection or oncologic resection, it is generally necessary to establish mandibular continuity prior to implant reconstruction. Contraindications to this surgical reconstruction relates to significant patient medical comorbidity, poor or uncertain oncologic prognosis or severe postirradiation compromise (decreased vascularity, cellularity and tissue hypoxia) (Figure 13.7).

Surgical technique

1. Vascularized or non-vascularized corticocancellous block bone grafts are harvested and skeletally fixed to the osseous defect. Non-vascularized block grafts are primarily obtained from the ilium or calvarium. When severe blood supply compromise is present, when the length of the discontinuity is excessive, or when vascularized soft tissue is required, harvest of vascularized composite bone grafts from various anatomic sites (most common include ilium, fibula or scapula) when bone and/or soft tissue is required, radial, abdominal, lateral thigh or various perforator grafts are indicated when only soft tissue is required. On occasion, various non-vascularized bone grafts are combined with vascular soft-tissue grafts (vascularized abdominal with non-vascularized ilium).



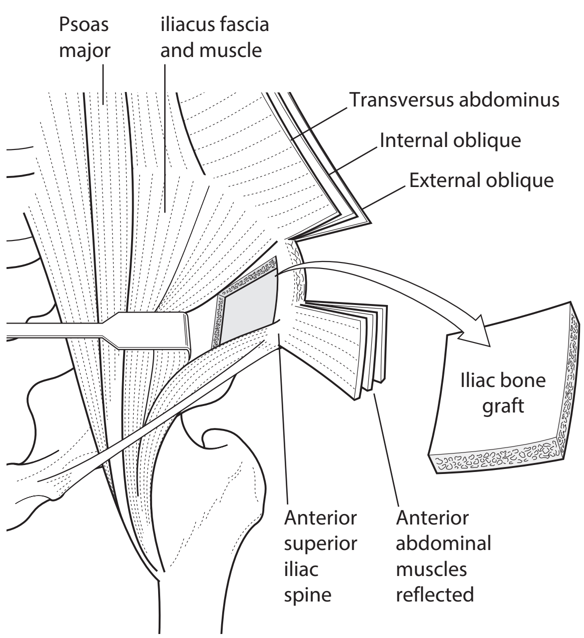


Figure 13.7 Mandibular oncologic or post-traumatic (two stage) corticocancellous iliac block bone graft with titanium mesh tray (stage I) and titanium endosseous implants (stage II).

2. Endosseous implants are placed 4–6 months following bone grafts when revascularization and remineralization is nearly complete (two-stage procedure).
3. If bone grafting has been successful from a bone volume and bone position standpoint, endosseous implant reconstruction follows routine implant reconstruction techniques.
4. When placing implant into irradiated bone or into bone graft previously placed into irradiated tissue, special surgical protocol is followed and includes the following: meticulous atraumatic bone drilling with exuberant cooling, conservative periosteal reflection (bone gets all of its blood supply from the periosteum in heavily irradiated patients), meticulous bone tapping and meticulous soft-tissue closure in a non-tension everted watertight fashion.
5. Prosthetic reconstruction in irradiated patients requires fixed continuous prosthesis to avoid compromised soft-tissue loading.
6. Endosseous implants placed into the irradiated edentulous mandible are better placed in the interforaminal area where the central irradiation beam creates the least damage to bone and where the cortical/cancellous bone ratio is more favourable than the bone of the mandibular body or ramus of the same patient.

Mental and inferior alveolar nerve management in bone compromised patient

Indications

In the severely resorbed mandible, the mental and inferior alveolar nerves are generally either herniated at the crest of the ridge or are covered by relatively thin bone. The technique of unroofing and repositioning the herniated nerve is relatively straightforward and atraumatic. Once the nerve is uncovered, the incisive branch must be cut at least 2–3 mm anterior to the mental branch. This allows the nerve to be lifted from its canal and repositioned posteriorly away from the implant osteotomy site. If performed correctly, a short period (2–6 months) of paraesthesia and/or anaesthesia will follow. If a closed nerve injury (crushing and/or tearing with a rotary drill) is created in a situation where the exact location of the nerve is not appreciated, the long-term potential morbidity is much increased. The author feels a planned minor nerve injury is much preferred over an unplanned closed nerve injury. In addition, implant placement can be greatly enhanced in many situations (such as an atrophic mandible) where improved prosthesis biomechanical loading is achieved. In the mandibular unilateral posterior edentulous patient onlay bone grafting is more difficult, primarily because of the presence of the inferior alveolar nerve. In addition, an onlay block bone graft is technically difficult and more risky to the nerve than the anterior block graft reconstruction described earlier. For these two reasons, the author prefers unroofing and repositioning the nerve prior to

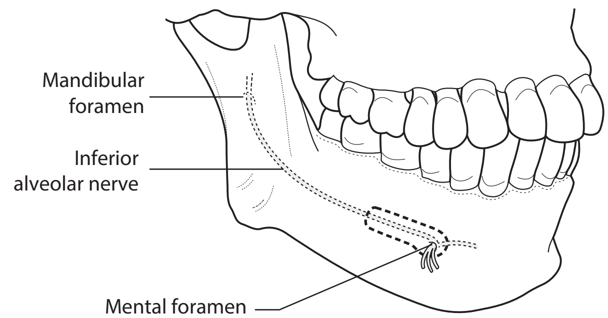


Figure 13.8 Surgical uncovering of mental/inferior alveolar nerve prior to endosseous implant reconstruction.

onlay bone grafting. In addition, frequently an onlay bone graft is not required once the nerve is out of the operative site. The surgical technique of uncovering and repositioning the mental and inferior alveolar nerve is illustrated in Figure 13.8, in the atrophic edentulous mandible and the posterior partially edentulous mandible. Surgical instrumentation is minimal and simple and consists of small round high-speed drilling burrs and small No. 2 and a No. 4 molt curette.

MEMBRANES AND BIOLOGIC HEALING ADJUNCTS

Membranes

The author uses very little, if any, alloplastic membranes in bone-grafted patients. Since the periosteum is highly osteogenic and provides significant rigidity and anatomic confinement, its proper use and positioning is preferred. This frequently requires a selective periosteal release (incision) at the height of a flap to allow it to be advanced over a bone-grafted area. The elastic fibres immediately above the periosteum permits up to 12 mm of flap advancement once the periosteum is accurately incised, a significant distance from the surgical defect to be covered. The antrum membrane is also highly osteogenic and can provide adequate confinement of a particulate graft (in addition to its osteogenic potential). If a very thin antral membrane ruptures, an appropriate collagen material is the most physiologic replacement of either the periosteum or antral membrane. An even better solution in the author's opinion is the use of small cortical grafts properly stabilized with endosseous implants (one-stage procedure) or miniplates or screws (two-stage procedure) providing a predictable bone reconstruction of small antral or alveolar defects.

Autogenous biologic healing adjuncts

The hallmark of predictable bone grafting augmentation and endosseous implant reconstruction of various

anatomic defects is meticulous and biologically sound surgical planning and surgical technique. Most healing failures follow faulty diagnosis (wrong surgery for a given problem), faulty patient selection (medical or psychologic comorbidities) or faulty surgical technique. The latter include excessive tissue destruction (cautery, laser, tearing or crushing of tissue), poorly designed or poorly vascularized tissue flaps, inadequate haemostasis leading to hematoma, failure to eliminate dead space with drains or suturing, devitalizing bone with excessive heat and failure to achieve watertight non-tension soft-tissue (mucosa–periosteum) closure. Extraoral approaches to the mandible where incisions are placed low in the neck potentially eliminate or reduce all the skin arterial perforators and reduce subcutaneous fat. This blood supply compromise combined with excessive cautery and thinning of the skin provides poor soft-tissue coverage of the osseous reconstructive efforts. Biologic enhancers will not cover up compromised surgery, but may enhance outcome if all other wound conditions are satisfied. The latter, however, has not been established to date by properly designed prospective studies.

BONE GRAFT HARVESTING TECHNIQUES

Adjunctive bone grafting for all but the most simple osseous defects warrant utilization of fresh autogenous bone which most agree represents the well-established gold standard of care.

Ideally, the bone graft should provide adequate bulk to repair the anatomic defect, act as a strong bone induction agent and provide viable osteogenic stem cells which provide transfer osteogenesis when placed in a closed biologic environment. The latter contains cellular nutrition and early revascularized potential. This graft must also be covered with a viable periosteum (osteoblasts) and surrounded with viable bone (cambium layer osteoblasts) to take advantage of the osteoinductive properties of the bone graft. Proper rigid stabilization of the graft is critical to ensure more specialized bone regeneration rather than less specialized collagen production in the osseous defect. The corticocancellous block or cancellous particulate bone from the ilium satisfies most, if not all, of the aforementioned attributes if properly harvested. Stabilizing the particulate grafts can become a problem which can lead to a loss of significant graft volume. Cortical grafts from the cranium or mandible, if properly harvested, can provide all but the transfer osteogenic component listed earlier. Atraumatic harvesting of the bone grafts is just as important as atraumatic preparation of the recipient site. Both are required for predictable bone grafting success. Ideally, the recipient site should be fully prepared before the bone graft is harvested. This allows immediate transfer of the bone graft to the recipient site which theoretically helps preserve the osteoinductive (protein) and transfer osteogenic (cellular) potential. When proper healing occurs, the bone graft will respond properly to physiologic loading (Wolff's law). The latter will not theoretically occur with allogenic bone grafts which may take years to be replaced with normal bone. The latter will provide osseous bulk, but not viable bone which responds appropriately to physiologic loading of an endosseous osseointegrated implant.

Top tips

- Advanced maxillary bone graft reconstruction requires autogenous corticocancellous block onlay, inlay or interpositional bone grafting. Each type (onlay versus inlay versus interpositional) has specific indications and can be either one or two stage.
- Bone graft reconstruction of small- to medium-sized congenital alveolar–palatal defects requires corticocancellous block bone grafts to completely restore the nasal floor, palate and piriform rim to achieve the most ideal nasal and dental implant aesthetic result.
- The reconstructive surgeon, prosthodontist and patient need to decide whether to replace lost anatomy or obturate lost anatomy in early planning of corrective surgery for large postsurgical or post-traumatic maxillary defects.
- Endosseous implant reconstruction of advanced bone resorption of the edentulous mandible can be achieved with a minimum of 5 mm of bone height and 6 mm of bone width.
- Bone regeneration of severely resorbed mandibular body occurs following functional loading of osseointegrated endosseous dental implants placed in the mandibular symphysis region (Wolff's law of bone physiology).
- Mandibular discontinuity reconstruction with vascularized or non-vascularized block bone grafts requires metal trays or reconstruction plates which are physiologic to avoid bone graft stress shielding during bone graft healing.
- A planned minor nerve injury is preferred to an unplanned major nerve injury when placing endosseous implants close to the inferior alveolar and metal nerve. Therefore, nerve uncovering and removal from the surgical site may be prudent.
- The periosteum provides the most physiologic and effective barrier membrane in all bone grafting situations. This requires selective periosteum incision and repositioning techniques.
- Autogenous bone graft harvesting surgical techniques must be atraumatic to preserve the bone induction (bioactive protein), bone conduction and transfer osteogenic (cellular) potential required for maximum bone graft regeneration.
- Atraumatic management of the covering mucoperiosteum or skin is required to provide a physiologic environment for predictable bone graft regeneration.

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14

Craniofacial implantology

GREG BOYES-VARLEY and DALE HOWES

CONTENTS

INTRODUCTION AND REVIEW OF THE LITERATURE

Modified reconstruction procedures are applied when the facial skeleton has insufficient bone for conventional implant placement. Extensive bone grafting is recommended to create adequate bone volume for placement of endosseous implants to restore the severely resorbed or resected maxilla with a fixed prosthesis. Bone grafting procedures include onlay grafts, inlay grafts into the floor of the maxillary antrum and Le Fort I maxillary osteotomy with advancement and down grafting techniques. Newly grafted bone has to remain load-free to allow consolidation and revascularization for 4 months. Staged bone graft techniques increase treatment time, which is tedious and socially unacceptable for the patient.

ANGULATED IMPLANTOLOGY–ZYGOMATIC IMPLANTS

Maxillary atrophy makes quality of life for denture wearer's unbearable, made worse by continuous bone resorption and maxillary sinus pneumatization.[1] The zygomatic implant has provided the clinician with an alternative to grafting procedures in the reconstruction of the severely resorbed maxilla. Branemark originally designed the technique in 1989 and has a reported success rate of 97%.

This implant traverses the posterior maxillary alveolus and lateral sinus wall into the body of the zygoma. The restorative interface requires angular correction from the long axis to allow for appropriate tooth position. Boyes-Varley et al. (2003) described the use of a 55° restorative head (Southern Implants™, Irene, South Africa) in order to reduce the buccal cantilever by 20%. The use of a modified head angulation of 55° with implant placement as close to the crest of the edentulous ridge as possible allows restorative clinicians to achieve an ideal restorative position in the posterior maxilla.[2]

Diagnostic radiology

Radiological assessment for the zygomatic implant protocol is used to detect the presence of pathology within the maxillary sinuses and to evaluate the volume of bone available in the maxillary alveolus and zygomatic body.

The following radiographic views are recommended:

1. Panoramic view to detect bone height within the maxilla and anatomical structures.
2. Occipito-mental views to assess the extent of the maxillary sinus and presence of sinus pathology.
3. Lateral cephalogram to assess jaw relationship.

4. Axial, coronal and reformatted computerized axial tomography (CAT) scans give an excellent assessment of the maxilla and maxillary sinus. In the case of cancer and trauma surgery patients, three-dimensional (3D) spiral reconstructions are useful and the DICOM data is used to manufacture a stereolithographic model for planned surgical resection and thus prosthodontic rehabilitation after resection. With the advent of cone beam computerized tomography scan (CBCT) technology, it may not be necessary to obtain a medical CAT scan in every case and much valuable information can be obtained from using a full volume CBCT (Figure 14.1).

Optimal implant placement is dictated by the position of three distinct anatomical sites:

1. The position of the incisura between the zygomatic arch and the frontal process of the zygomatic bone (Point A).
2. The confines of the lateral wall of the maxillary antrum (Point B).
3. The thickness of the existing alveolar crest (Point C) (Figure 14.2).

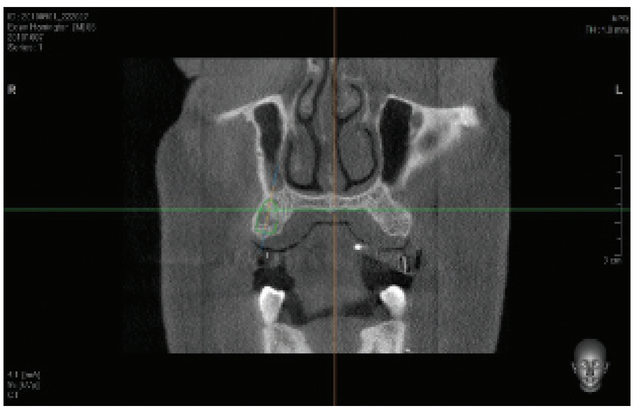


Figure 14.1 Cone beam CAT scan of the maxilla.

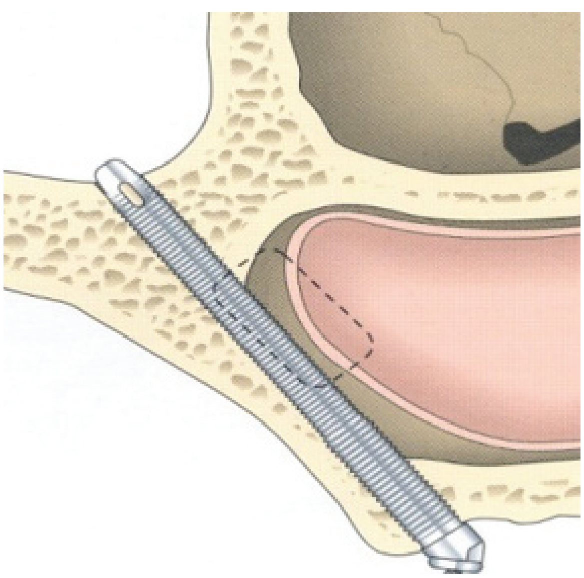


Figure 14.2 Drawing of the maxilla and zygoma (coronal).

For optimal implant placement, the position of the incisura of the zygoma is fixed and provides the superior pivot point of the zygoma implant. Occasionally, the surgeon can place the exit point of the implant more medially towards the infero-lateral orbital margin and great care should be taken to avoid perforation into the infero-lateral aspect of the orbit. This uprights the implant and brings the restorative head into the first molar site instead of the second premolar site (Figure 14.3).

The lateral wall of the sinus is engaged by the implant as far laterally as possible to obtain the most lateral position of the implant in the sinus wall. The head of the implant in the maxillary alveolus is placed as close to the mid-alveolar position of the ridge as possible (Figure 14.4).

Surgical technique

Placement of zygomatic implants is usually performed under general anaesthesia. A crestal incision is made extending from 1 cm in front of the maxillary tuberosity to the same position on the contra-lateral side. Periosteal elevation results in the exposure of the entire maxilla, around the base of the piriform aperture, up to the inferior aspect of the infraorbital nerves and exposing finally the inferior aspect of the body of the zygoma bilaterally.

A round bur is then used to create a lateral window in the supero-lateral aspect of the maxillary antrum, with sinus

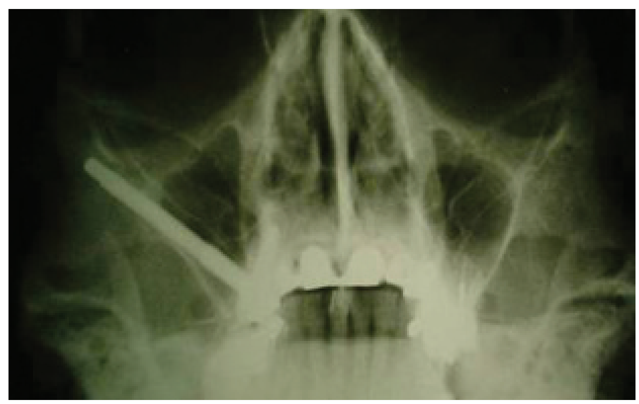


Figure 14.3 Occipito-mental radiograph of the maxilla.

Figure 14.4 Lateral maxillary wall.

mucosa reflection. Using a round burr, the proposed point of entry of the fixture into the zygomatic bone is demarcated through the sinus window (Figures 14.2, 14.5 through 14.7).

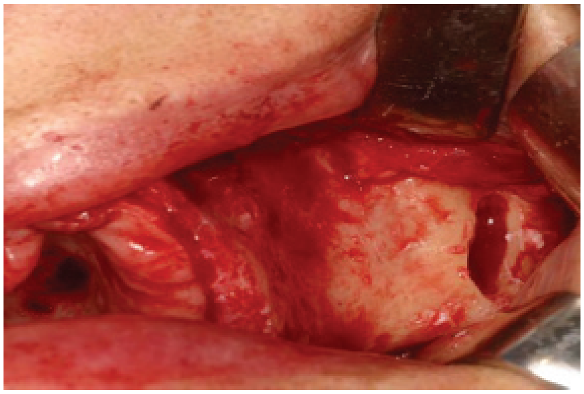


Figure 14.5 Osteotomy in supero-lateral sinus wall.

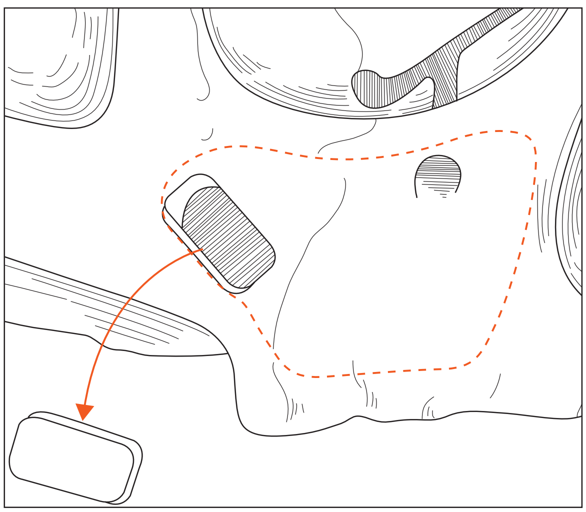


Figure 14.6 Diagram of window in the superolateral maxillary wall.

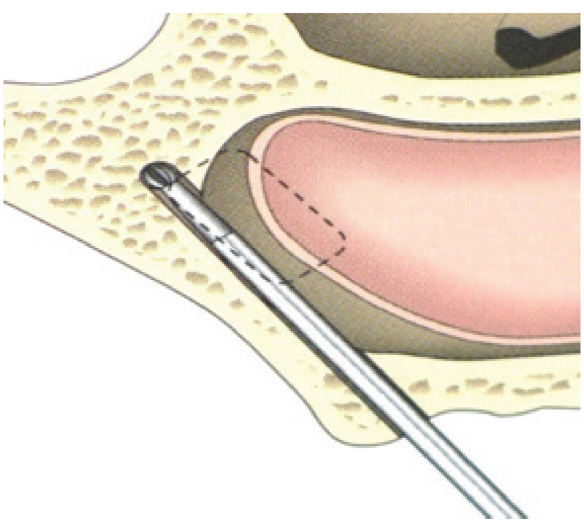


Figure 14.7 Initial pilot drill.

The final site preparation follows the graded pilot and twist drills. Care should be taken to not perforate the bony orbit with subsequent disruption of the orbital contents (Figures 14.8 and 14.9).

Impiant placement

A zygomatic implant with a head angulation of 55° (Southern Implants®, Irene, South Africa) is the preferred implant as this improves the emergence profile and decreases the buccal cantilever (Figures 14.10 and 14.11).

Final placement of the fixture is accomplished by ensuring proper angulation of the implant platform by placement of a guide pin into the implant and the fixture rotation to ensure optimal position (Figure 14.12).

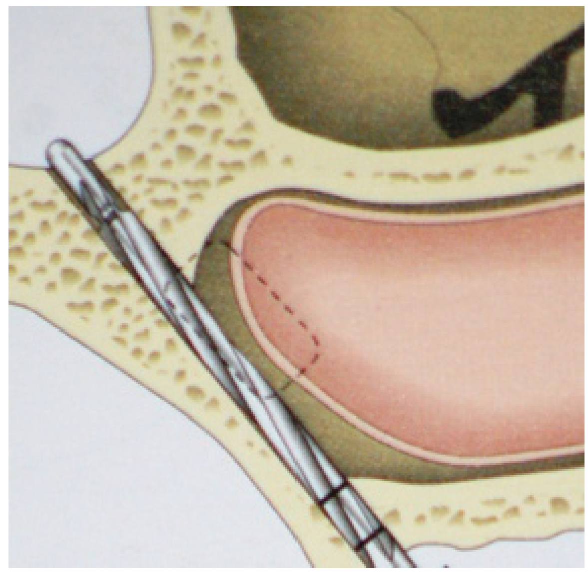


Figure 14.8 Diagram of final drill.

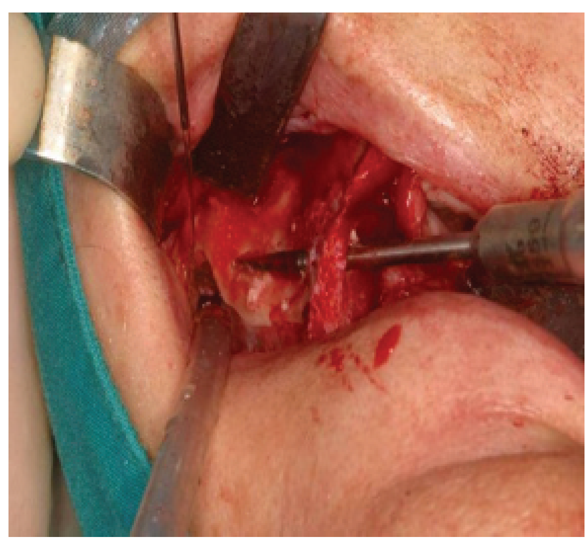


Figure 14.9 Final drill into the zygoma, trans maxillary.

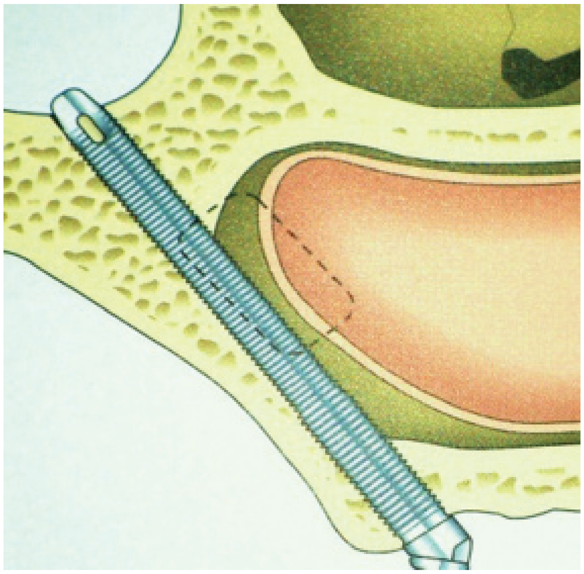


Figure 14.10 Implant in situ.

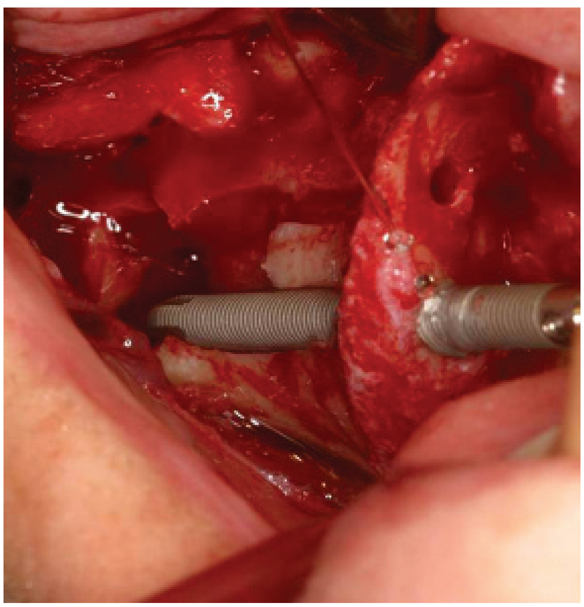


Figure 14.11 Implant into the osteotomy site.

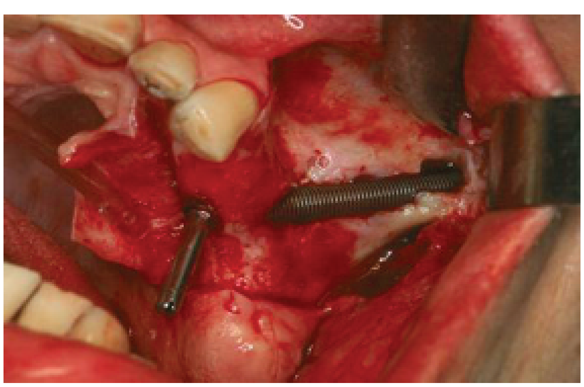


Figure 14.12 Final implant position.

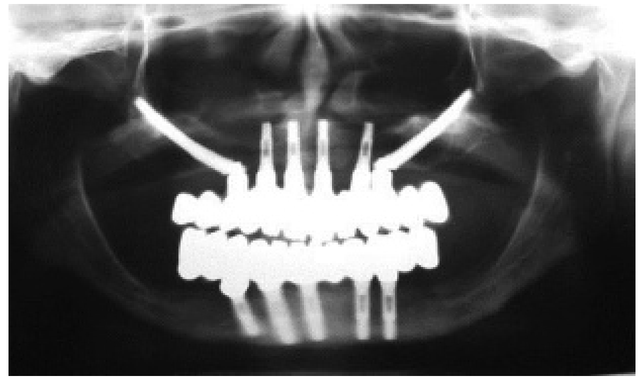


Figure 14.13 Radiograph of restored implants.

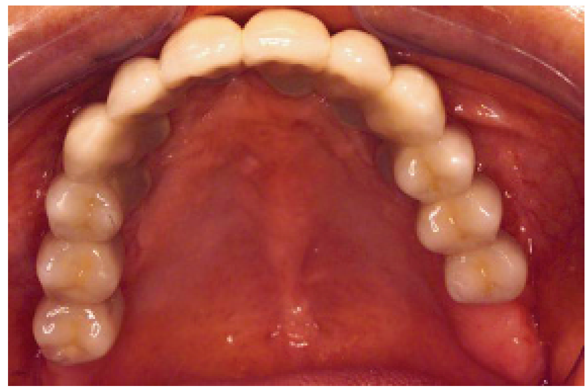


Figure 14.14 Final prosthesis.

Standard protocol is two zygomatic implants placed posteriorly with four paranasal implants and a fixed porcelain fused to titanium prosthesis (Figures 14.13 and 14.14).

HEMIZYGOMATIC IMPLANTS

Reconstruction of hemi-maxillary defects in partially dentate patients where there has been premolar and molar loss often predisposes to sinus pneumatization with minimal bone in this area for conventional implant placement. Treatment options include a unilateral sinus graft or the utilization of a hemi-zygomatic protocol with the placement of one standard endosseous fixture and a zygomatic in the posterior maxillary region (Figures 14.15 through 14.19).

QUADRATIC ZYGOMATIC IMPLANTS

Balshi et al. (2003) described the use of multiple zygomatic implants in reconstruction of the atrophic maxilla and proposed the use of up to three zygomatic implants per quadrant. Our clinical experience has shown that using only two zygomatic fixtures per quadrant has proved adequate for the rehabilitation of the atrophic maxilla with

fixed or fixed hybrid prosthesis. An autogenous bone graft can be avoided and is advantageous as the patient is saved the morbidity and possible complications of a bone graft.

Figure 14.15 Radiograph of hemi.

Figure 14.16 Anatomical defect.

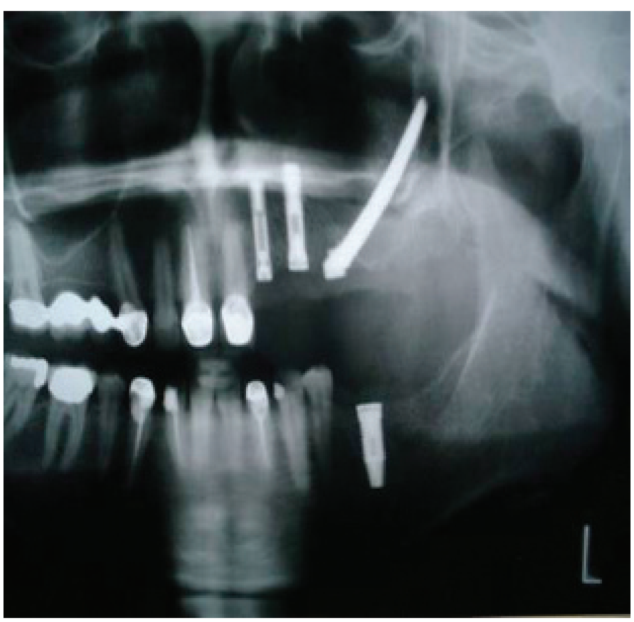


Figure 14.17 Implant positions at placement.

This allows for an arch of 10–12 teeth even in patients with inadequate anterior width and height of bone (Figures 14.20 through 14.22).

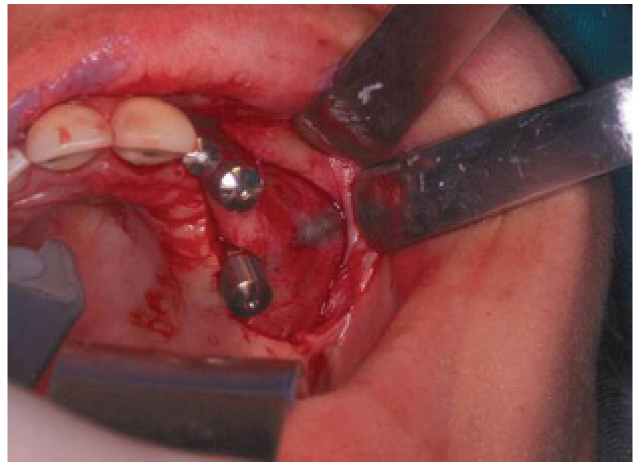


Figure 14.18 Implants at exposure.

Figure 14.19 Final prosthesis.

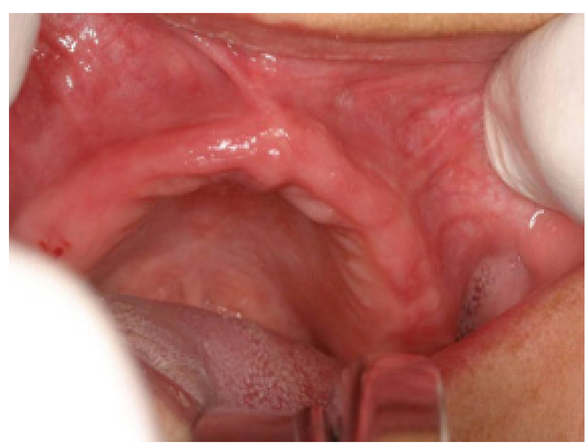


Figure 14.20 Edentulous ridge.

Surgical technique

Quad zygomatic implant placement is usually the placement of two zygomatic implants into each side of the maxilla, usually the first fixture placed into the premolar site and the second into the canine or lateral incisor positions. The surgical technique is as for standard zygomatic fixture placement and a more palatal mucosal incision is made to include an adequate band of attached mucosa (Figures 14.23 through 14.29).

Care should be taken to not perforate into the inferolateral aspect of the orbit with the implant body in the canine site. Post-operative radiology is thus mandatory.

It is possible to immediately load these implants with a fixed hybrid acrylic strengthened prosthesis, which remains in place for the three to 4 months whilst healing takes place (Figures 14.30 through 14.32).

This avoids a second procedure to expose the implants 4 months after placement. This has a cost implication since hospital stay, theatre time and recovery time are all reduced allowing the patient to be integrated back into society quicker. After healing has taken place, the temporary prostheses are replaced with fixed porcelain fused to titanium prosthesis (Figures 14.33 through 14.34).

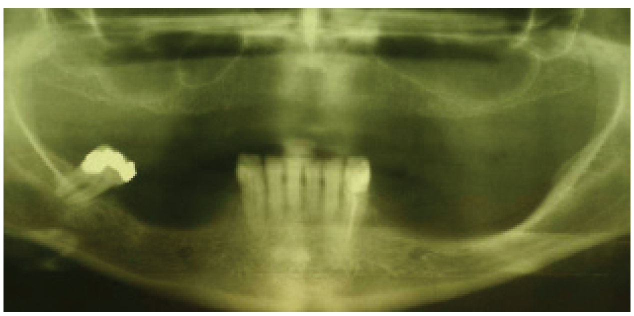


Figure 14.21 Panoramic radiograph.

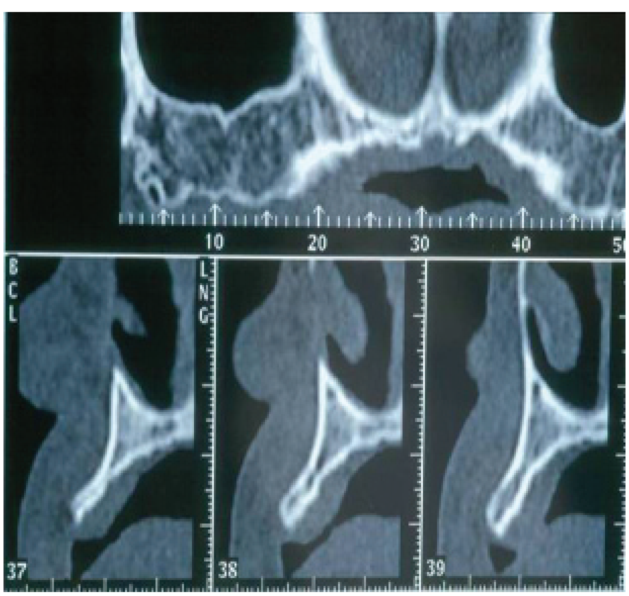


Figure 14.22 Cone beam CAT scan of maxilla.

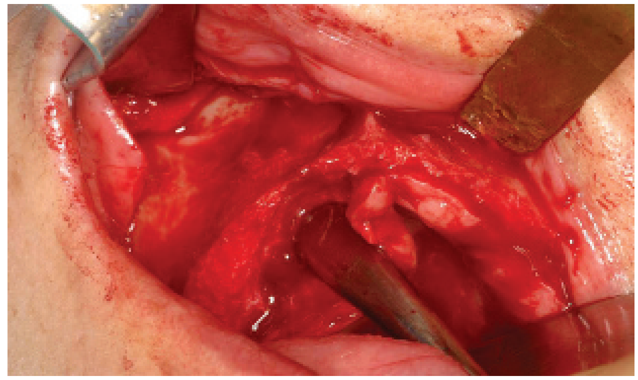


Figure 14.23 Exposed edentulous ridge.

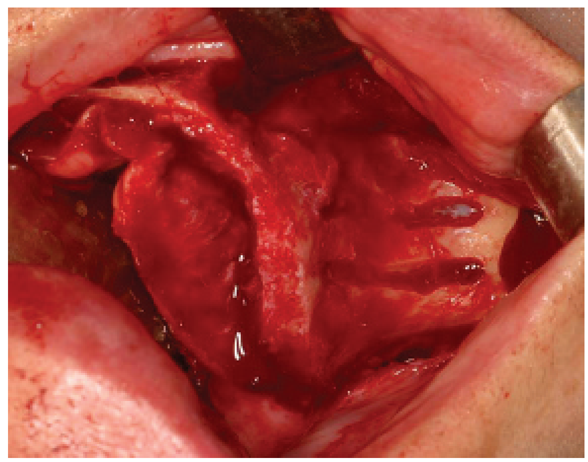


Figure 14.24 Osteotomy sites in the left maxilla.

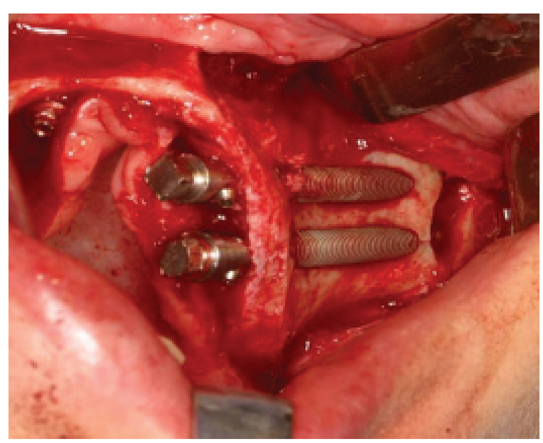


Figure 14.25 Implants in situ.

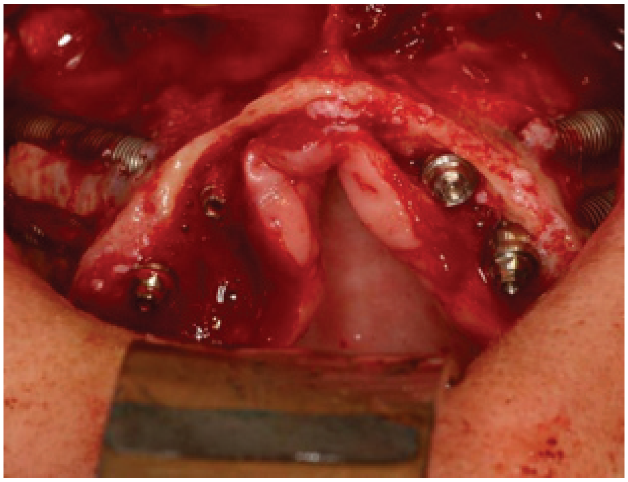


Figure 14.26 Occlusal view.

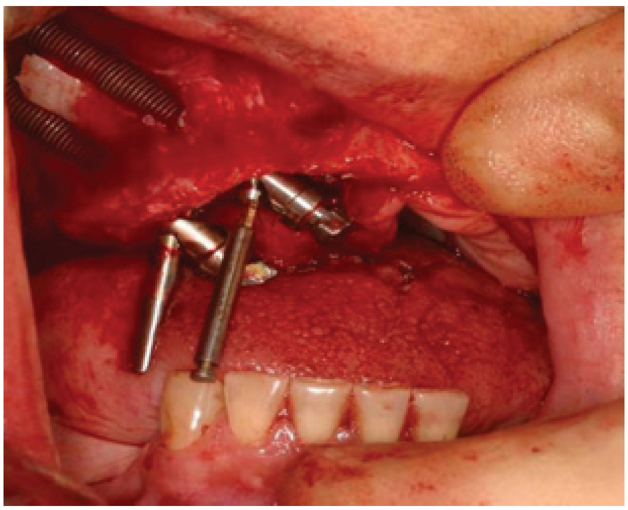


Figure 14.27 Indicator projection.

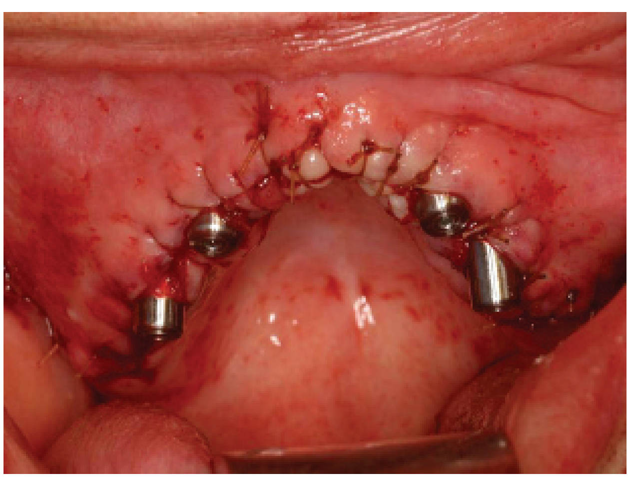


Figure 14.28 Implants exposed.

Figure 14.29 Occipito-mental radiograph.

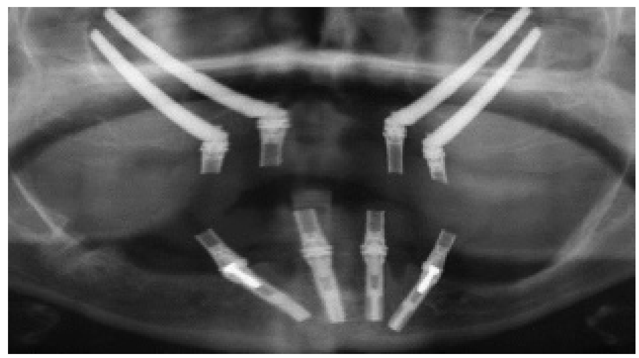


Figure 14.30 Radiograph of implants in situ.

Figure 14.31 Temp prosthesis.

Figure 14.32 Occlusal view.

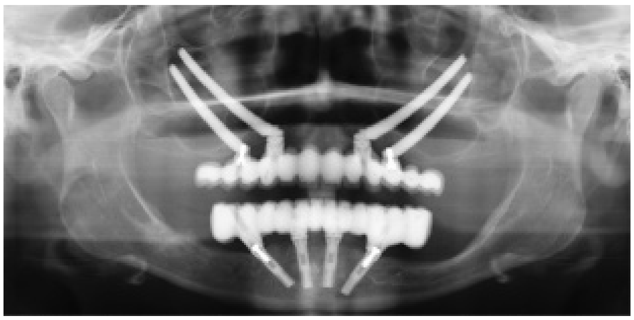


Figure 14.33 Final radiograph.

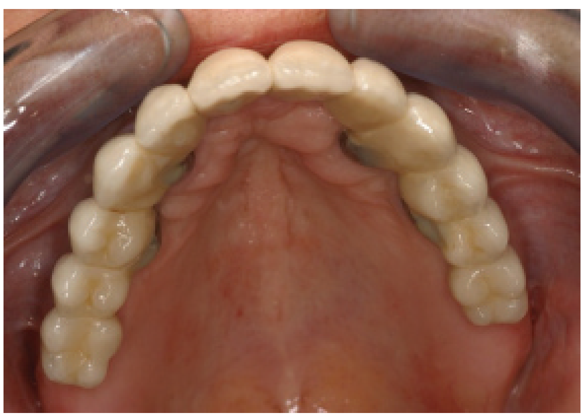


Figure 14.34 Final prosthesis.

ZYGOMA, ZYGOMATIC IMPLANTS AND ONCOLOGY RECONSTRUCTION

Tumour ablative surgery and trauma to the mid facial complex involves structures integral to phonetics, deglutition and mastication and makes reconstruction both difficult and controversial. The surgery is complex and involves sealing of the oral cavity from the nasal cavity, reestablishment of the paranasal sinuses and restoration of the facial contour.[1] Dental rehabilitation is also a massive functional and aesthetic consideration that should be considered when planning the proposed reconstruction.[2]

Several methods have been proposed for post-surgical reconstruction.[3] Reconstruction depends on the extent of the resultant bony and soft-tissue defect and obturation requires a working relationship between the surgical and prosthetic teams. The prosthetic design has evolved over decades[4] and osseointegration has revolutionized facial reconstruction in these cases. This technology can mostly circumvent the need for vascularized osseomyocutaneous grafts or these grafts in combination with non-vascularized free bone grafts. The advantage of endosseous implant rehabilitation over vascularized free flaps is the ability of the surgeon being able to inspect the resection cavity for recurrent disease. Visual inspection for recurrences in today,s world is trumped by interval radiographic assessment, with the use of computerized tomography (CT), magnetic resonance imaging (MRI) and positron emission tomography (PET) scans. These investigations are costly, are often unavailable to patients with recurrent disease and make maxillary rehabilitation with endosseous implants a more viable and inexpensive treatment modality. The placement of endosseous implants facilitates prosthodontic rehabilitation, which allows for secure, aesthetic and functional replacement of ablated hard and soft tissues and minimizes the disadvantages of silicone bulbs, obturators and dentures.

Oncology reconstructive protocol

Phase 1: Diagnosis

Patients requiring resection for oncology are subjected to a standardized pre-operative radiological survey. This includes routine orthopantomogram, occipito-mental views, lateral cephalogram taken in occlusion and CAT scan of the affected area and neck (Figures 14.35 and 14.36).

Incisional biopsy of the tumour is performed to obtain a definitive histological diagnosis and tumour grading and helps to establish the surgical and post-operative chemotherapeutic or radiotherapy protocols.

Prosthodontic preparation and stereolithographic simulated surgery

Where possible a stereolithographic acrylic model is grown from the DICOM Format CT scanning data. Resection surgery is simulated on this model and allows for optimal implant positions and conformation of prosthetic design (Figures 14.5 through 14.7) and diagnostic casts are modified according to the expected resection and a surgical obturator prepared and a temporary obturator made (Figures 14.37 through 14.40).

Further pre-operative reconstructive planning is also carried out at this stage and with possible free vascularized free flap or implant supported obturation techniques decided upon using computer-generated reconstructive techniques (Figure 14.41).

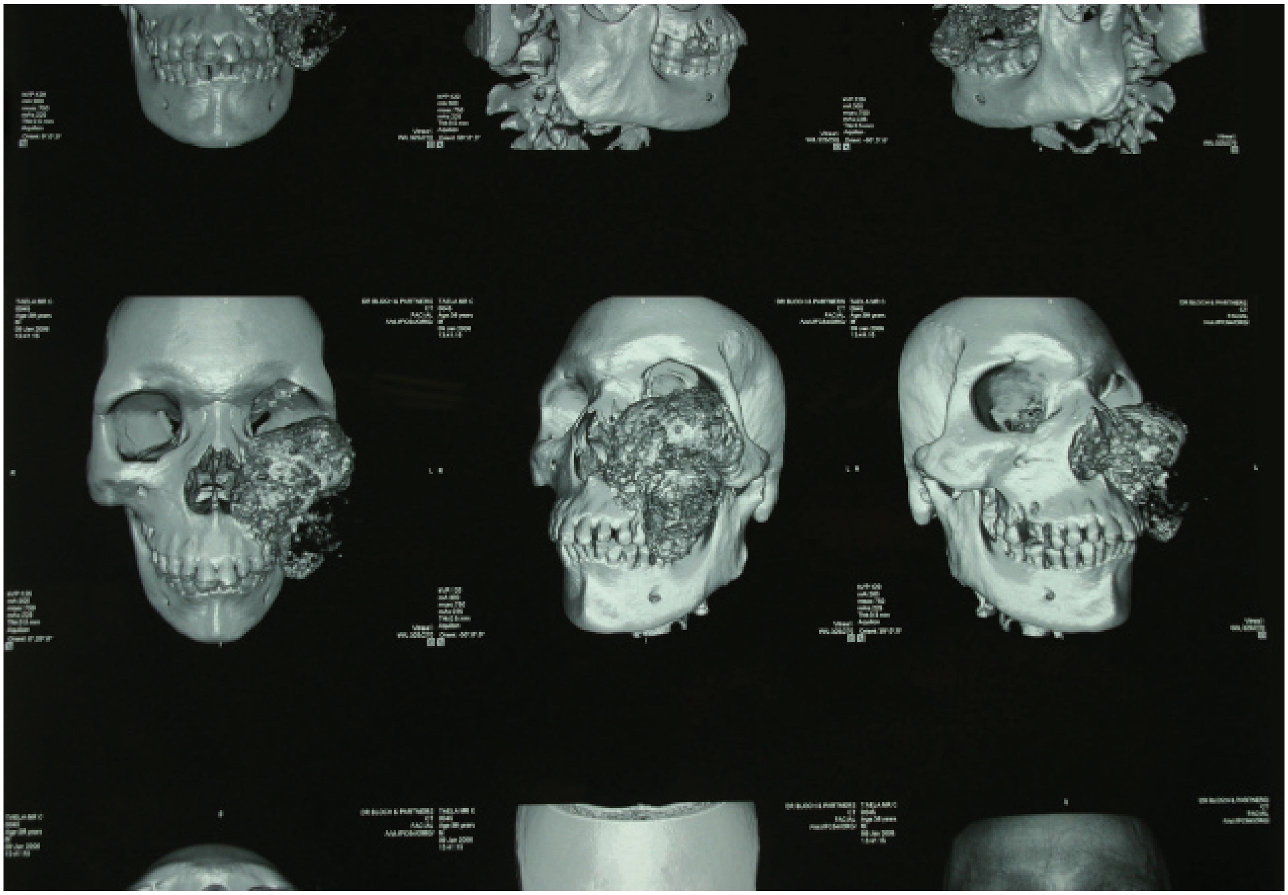


Figure 14.35 CAT scan of maxillary tumour.

Figure 14.36 CAT scan of maxillary tumour.

Phase 2: Tumour resection, immediate implant placement and obturation

Airway management is achieved most often by tracheostomy. Extra-oral access to the tumour is achieved in most cases by a modified Weber-Ferguson flap with a wide soft-tissue resection margin and hemi-maxillectomy (Figures 14.42 through 14.44). After tumour resection, frozen sections of the resection margin are done to ensure complete tumour excision.

Implant placement

The objective of implant placement is to 'recreate' the buttresses and processes of the maxilla allowing for appropriate force distribution of the prosthetic rehabilitation with the remaining facial skeleton. Both standard and zygomatic implants are used to and zygomatic implants (or a modified zygomatic 'oncology' implant) allows for the lowering of the restorative platform at least to the level of the palate (Figures 14.45 and 14.46).

The zygoma fixture was modified for insertion into the resection stump, with the soft-tissue portion of the implant being a smooth machined surface (Southern Implants^{TM}, Irene, South Africa) (Figures 14.47 and 14.48).

A low nasal antrostomy is performed at the floor of the intact sinus allowing for drainage of the maxillary sinus inferiorly as well as through the osteum (Figures 14.49 and 14.50). The zygoma fixture was modified for insertion into the maxillary resection stump, with the soft tissue portion of the implant being a smooth machined surface (Southern Implants TM, Irene, South Africa)

Figure 14.37 CAT scan.

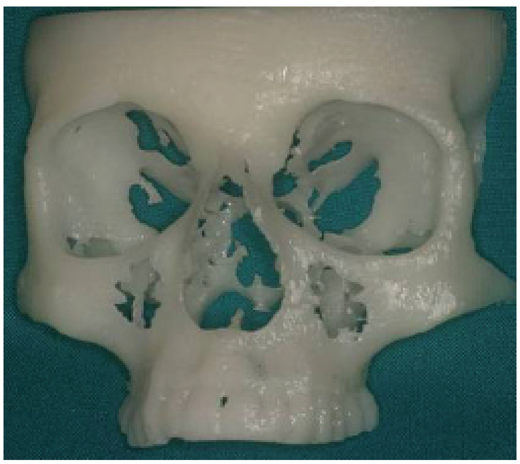


Figure 14.38 Stereolithographic model.

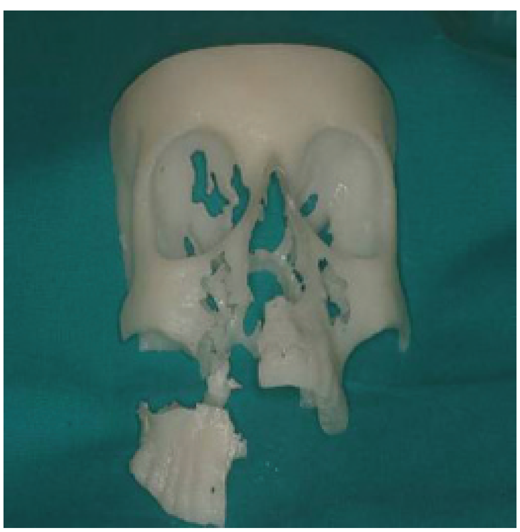


Figure 14.39 Simulated surgery.

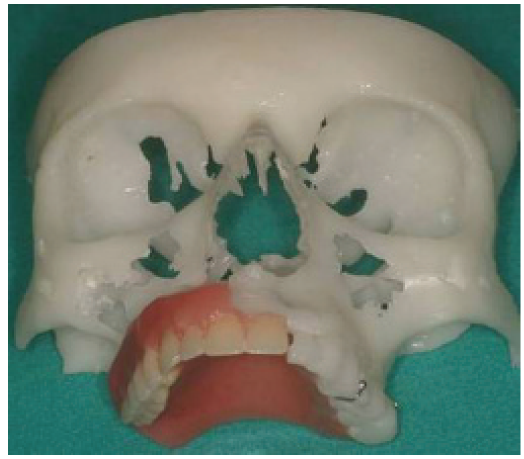


Figure 14.40 Confirmation of obturator design.

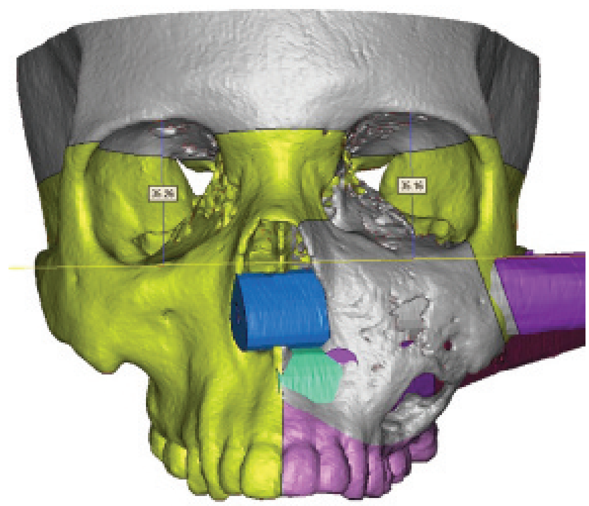


Figure 14.41 Computer-generated model.

Figure 14.42 Tumour in palate.

Figure 14.43 Weber-Ferguson incision shown.

Figure 14.44 Resected tumour.

(Figures 14.50 and 14.51) A low nasal antrostomy is performed at the floor of the intact sinus allowing for drainage of the maxillary sinus inferiorly as well as though the osteum.

Surgical obturation

The surgical obturator is modified intra-operatively after implant placement to restore normal soft-tissue facial contour over the resection site and guide soft-tissue healing. This obturator is secured by two 15 mm trans-osseous titanium screws in the remaining palate and supported by the zygomatic implants on the affected side.

Soft-tissue closure

The Weber-Ferguson flap is closed with a two-layered technique, and a naso-gastric feeding tube placed in the contra-lateral nostril (Figure 14.51).

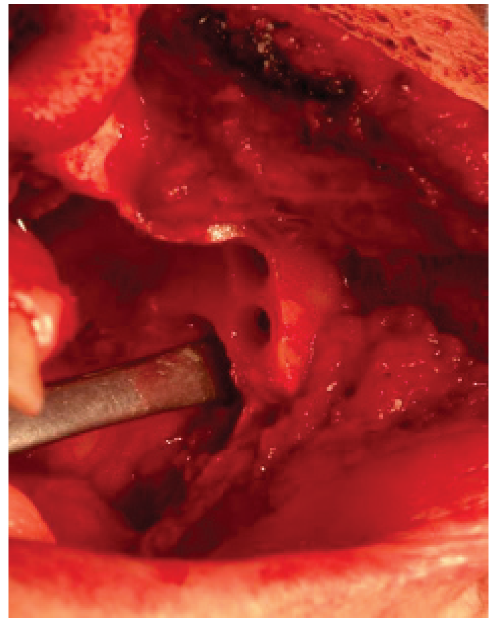


Figure 14.45 Resected maxilla.

Figure 14.46 Zygomatic implants into the zygomatic stump.

Figure 14.47 Position and angulation of zygomatic fixtures within the zygomatic stump projected towards the occlusal plane using the palatal height as a guide.

Figure 14.48 Position and angulation of zygomatic fixtures within the zygomatic stump projected towards the occlusal plane using the palatal height as a guide.

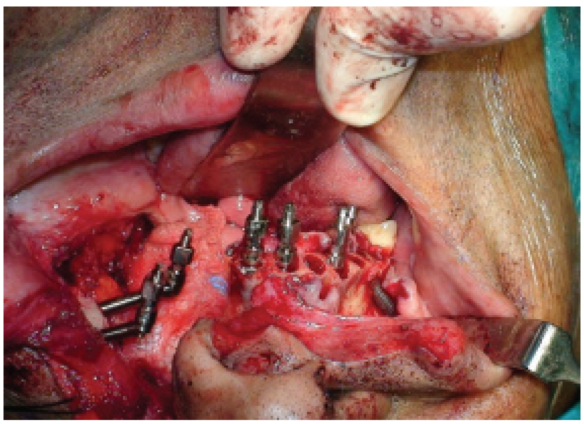


Figure 14.49 Oncology zygomatic implant in situ.

Figure 14.50 Oncology zygomatic implant.

Phase 5: Laboratory fabrication of definitive superstructure and interim obturator

Master casts are poured and mounted on an articulator by using the jaw relation from the modified duplicate surgical obturator. The super-structure and the interim obturator are then fabricated (Figures 14.52 and 14.53).

Prosthodontic rehabilitation can be achieved with an over denture protocol (examples are shown in Figures 14.54 and 14.55) or with fixed dento-alveolar elements and a separate removable implant supported obturator (Figures 14.56 through 14.58).

Figure 14.51 Closure of Weber-Ferguson flap.

Figure 14.52 Fixed prosthesis on model with interim obturator.

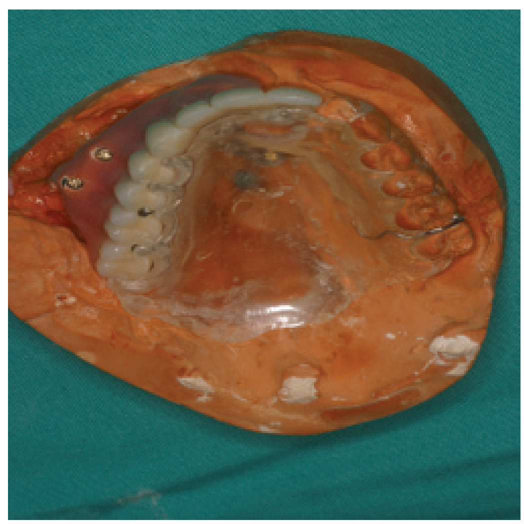


Figure 14.53 Interim obturator clipped onto fixed prosthesis.

Post-operative radiographs are taken to confirm the position of the implants within the bone and to ensure that the prosthesis is firmly to the implants (Figures 14.59 and 14.60).

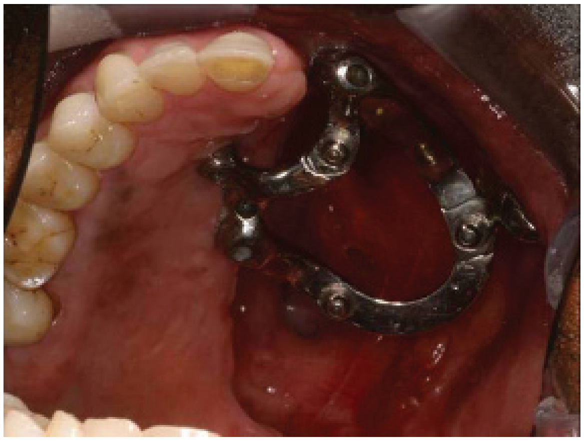


Figure 14.54 Definitive splinted super-structure with interim obturator on model.

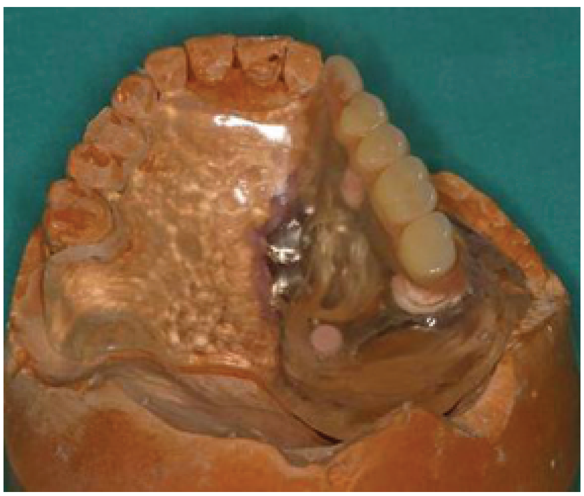


Figure 14.55 Definitive splinted super-structure with interim obturator on model.

Figure 14.56 Fixed prosthesis in situ.

Phase 8: Maintenance

The surgical site is monitored closely by both the oncologist and reconstructive teams for adequate post-operative healing and long-term recurrence. Prosthetic maintenance is ongoing, particularly in the first year, where soft-tissue changes can be extensive. The obturators may require continual peripheral adjustment and oral hygiene training is undertaken using brushing techniques and pulsating irrigation.

Occasionally the patient may request that the removable acrylic obturator be replaced with a soft tissue flap to completely close the oral from the nasal or antral environment. This may arise due to persistent air, fluid and food escape into the nasal cavity. In such cases, and once the patient has been investigated for tumour recurrence and has been found to be tumour free, a microvascular-free tissue may be used to completely close the oral cavity from the nasal cavity. The flap choices in these cases are either a radial forearm or anterolateral thigh microvascular free flap based on the facial artery on the resection side (Figure 14.60a–c).

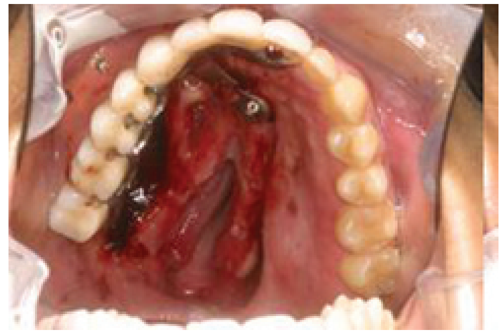


Figure 14.57 Fixed prosthesis with obturator.

Figure 14.58 Interim obturator.

Figure 14.59 Radiographs of implants.

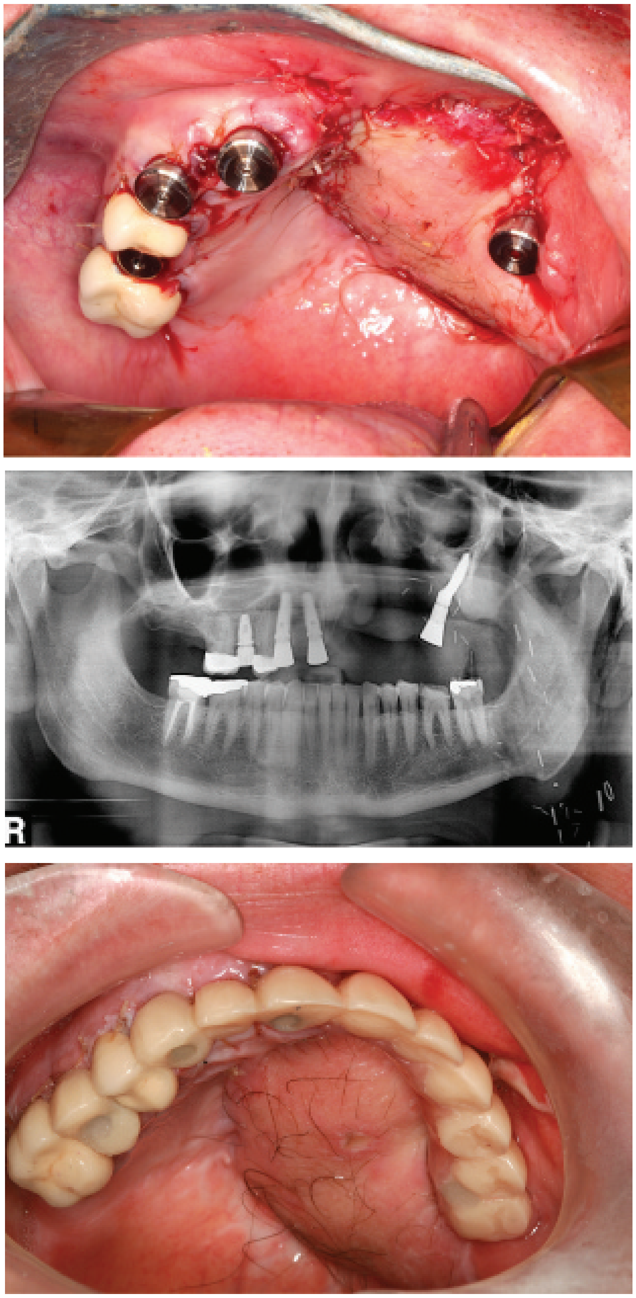


Figure 14.60 Radiographs of implants.

ZYGOMATIC IMPLANTS AND NASAL AND NASO-MAXILLARY RECONSTRUCTION

Oncology cases which present in the anterior maxilla often require anterior maxillary and nasal resection in order to resect the tumour. Rehabilitation in these cases often requires the provision of a combined intra-oral and extra-oral prosthesis (Figures 14.61 through 14.67).

Nasal prostheses are generally implant retained and a modified placement technique can be done to achieve enough anchorage to secure a nasal prosthesis. It involves the placement of two standard zygomatic fixtures almost horizontally in combination with standard implantology into the anterior maxillary floor (Figures 14.68 through 14.70).

Figure 14.61 Carcinoma of the nose.

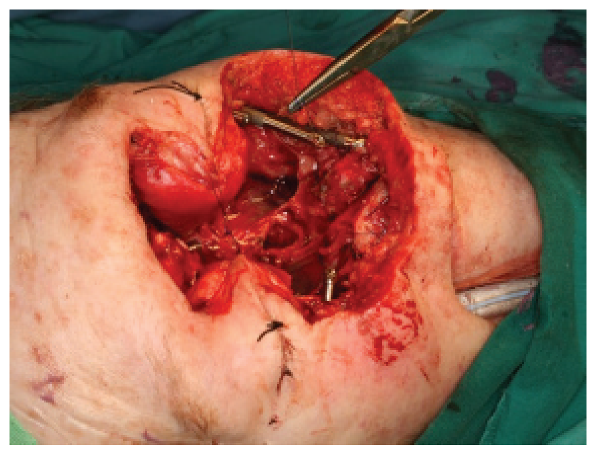


Figure 14.62 Facial resection with implants in situ.

Figure 14.63 Temporary prosthesis at resection.

Figure 14.64 Dolder bar attached to implants.

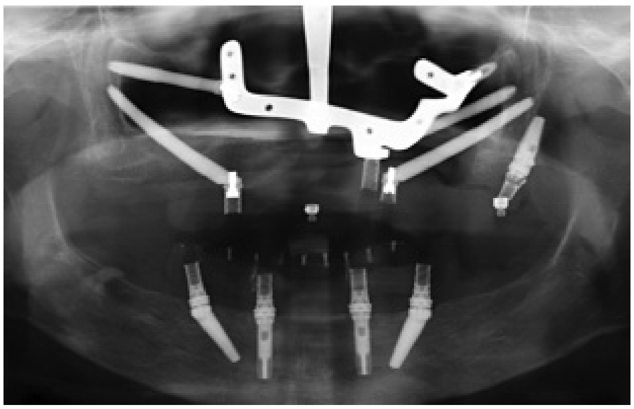


Figure 14.65 Radiograph of implants in face.

Figure 14.66 Facial prosthesis.

ZYGOMATIC IMPLANTS AND GUNSHOT RECONSTRUCTION

The rehabilitation of the midface after a gunshot wound to the face ablates structures which are in the path of the

Figure 14.67 Final prosthesis.

Figure 14.68 Nasal Dolder bar.

Figure 14.69 Radiograph of implants.

Figure 14.70 Interim obturator.

missile and the resultant facial deformities after gunshot wounds to the face can create serious psychological and aesthetic complications for the patients. Facial trauma from gunshot wounds is common in many countries, especially when sustained in war. Little has been published about reconstruction following gunshot wounds and other trauma to the face after anatomical disruption of the maxillofacial complex akin to oncology resection following hemi-maxillectomy and the treatment protocols used to rehabilitate these patients are similar to oncology reconstructions.

The area of cavitation which is produced between the entrance and exit wounds produces both hard and soft-tissue defects. There is a secondary missile effect of the bone and fractured tooth fragments and soft tissue is destroyed in the process. The initial treatment is aimed at resuscitation of the patient with debridement of the avulsed area and attempt to obtain soft-tissue closure and repositioning and reduction of facial bone fractures with titanium mini-plates (Figures 14.71 and 14.72).

Rehabilitation takes place roughly 3 months after initial repair of the hard and soft tissues. A full radiological examination is undertaken and this gives the restorative team the necessary information required to plan rehabilitation. 3D spiral CAT scan imaging is the most useful in this regard (Figure 14.73).

Facial gunshot wounds usually traverse the midline and the soft and hard tissue defects are best obturated to restore facial harmony. Occasionally, bone grafts are performed into the area and sort tissue defects are closed prior to bone grafting. Implant placement is done using a combination of standard and zygomatic implants and an immediate loading technique is employed (Figures 14.74 through 14.90).

Almost all maxillary defects resulting from anatomical disruption of the maxillofacial complex can be particularly well rehabilitated functionally and aesthetically using this

Figure 14.71 Gunshot of low-velocity bullet.

Figure 14.72 High-velocity bullet wound to the face.

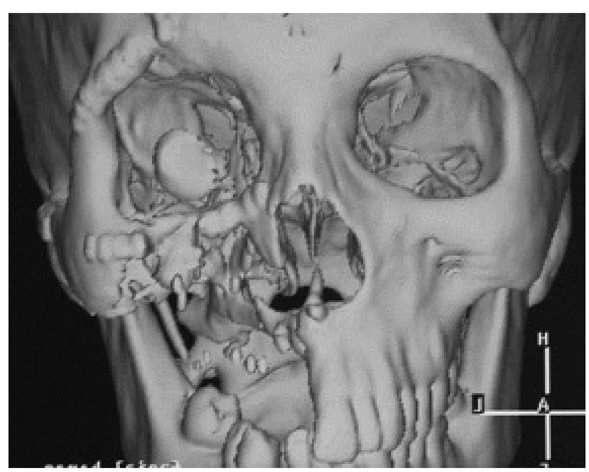


Figure 14.73 Post-op CAT scan of facial gunshot wound defect.

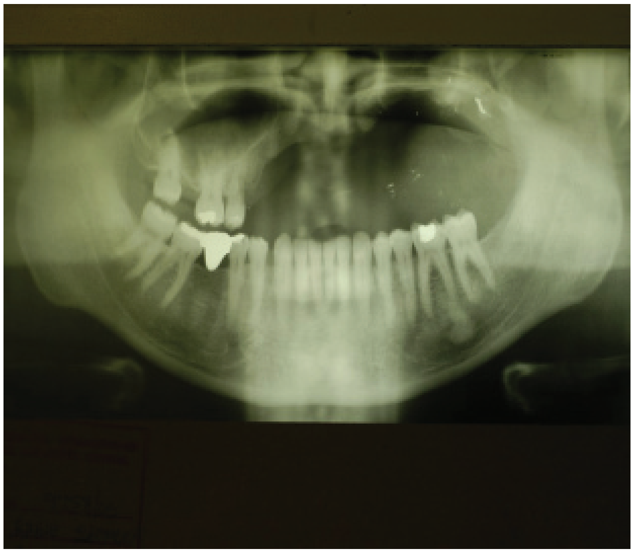


Figure 14.74 Panoramic radiograph.

Figure 14.75 CAT scan of resultant defect.

Figure 14.76 Intra-oral view of defect.

Figure 14.77 Lateral ceph of defect.

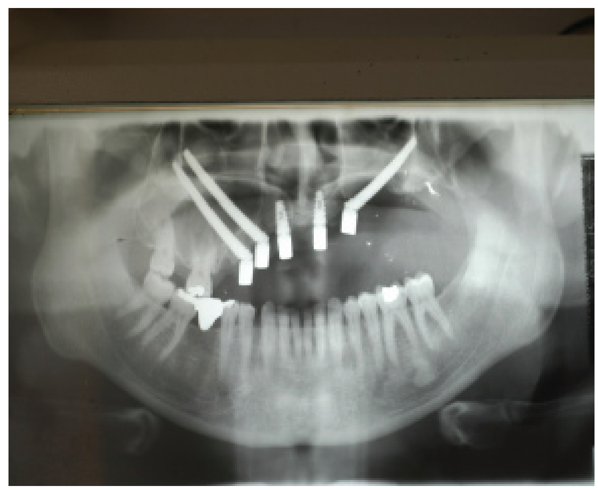


Figure 14.78 Implants position.

Figure 14.79 Interim fixed prosthesis.

Figure 14.80 Gunshot of low-velocity bullet.

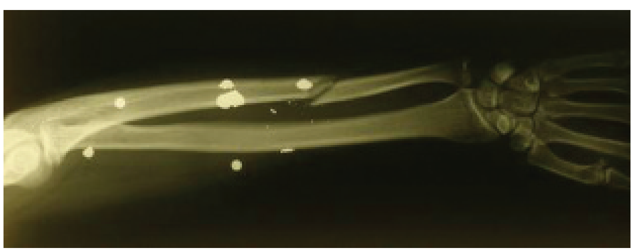


Figure 14.81 Shrapnel in the arm.

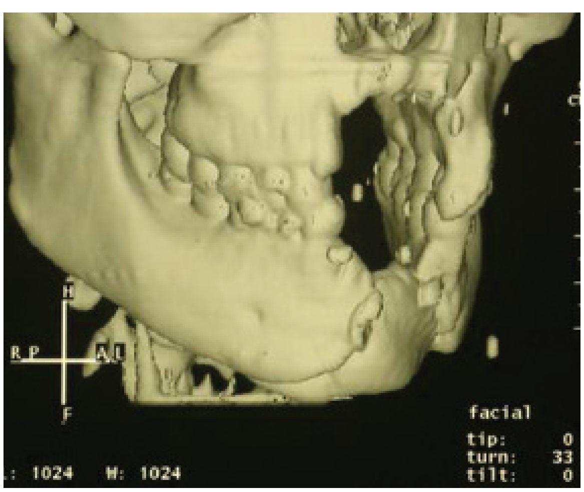


Figure 14.82 CAT scan of gunshot of low-velocity bullet.

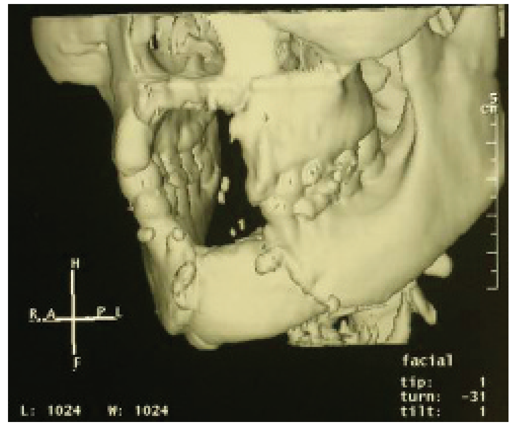


Figure 14.83 CAT scan of gunshot of low-velocity bullet.

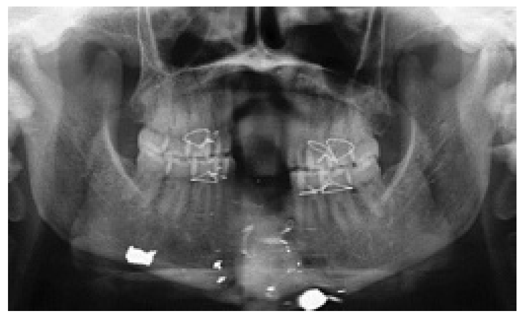


Figure 14.84 Panoramic radiograph.

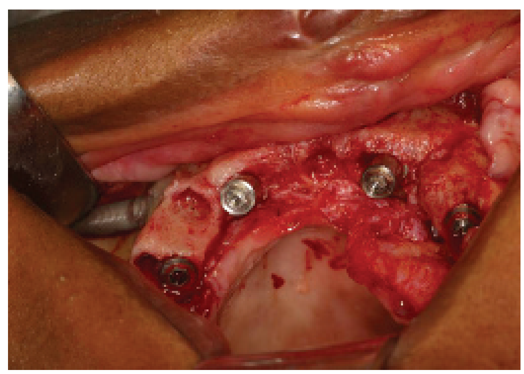


Figure 14.85 Gunshot reconstruction by zygoma implants.

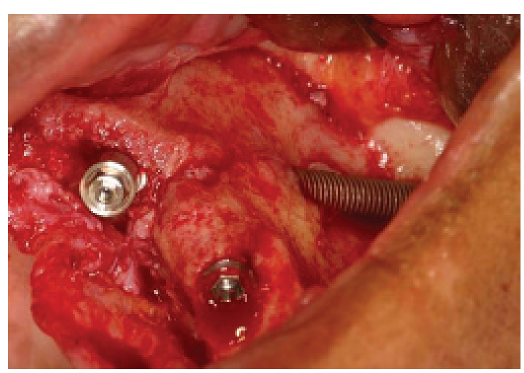


Figure 14.86 Gunshot reconstruction by zygoma implants.

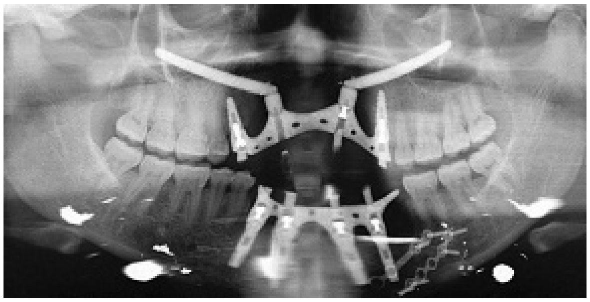


Figure 14.87 Panoramic radiograph of implants and super-structure.

Figure 14.88 Maxillary prosthesis.

Figure 14.89 Mandibular prosthesis.

protocol in conjunction with standard implantology and fixed/fixed-removable prosthodontic principles.

PTERYGOID IMPLANT

The posterior maxilla has limitations in the extent of the maxillary sinus and the tuberosity and pterygoid plate region is an alternative to sinus lifting procedures. The placement of a cone-shaped implant into this region requires the correct angulation and is placed into the maxillary tuberosity and angulated up the posterior wall of the maxillary antrum. This is technically demanding, has limited access and has an 85% success rate (Figure 14.91).

Figure 14.90 Facial soft-tissue repair.

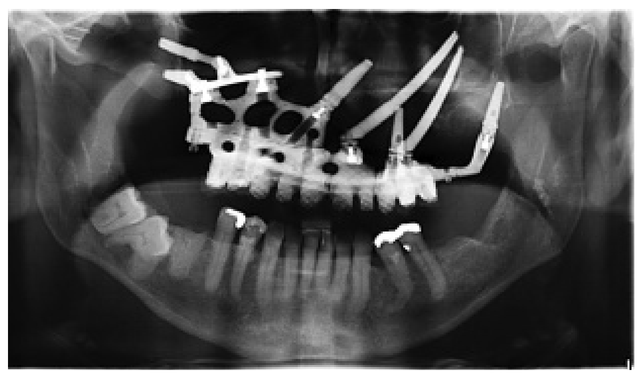


Figure 14.91 Oncology resection with pterygoid implant.

EXTRA-ORAL IMPLANTS—CRANIAL, AURICULAR AND ORBITAL

The placement of extra-oral implants to replace missing ears, eyes and cranium are accomplished with the placement of small length implants, which are placed into very dense regions of the frontal bone, supra orbital margin and temporal bone (Figures 14.92 through 14.94).

Auricular implants are placed into the temporal bone, roughly 20–22 mm behind the external auditory meatus and orbital implants into the supra orbital margin. These implants are usually about 4–5 mm in length and are splinted by a titanium Dolder bar, onto which the auricular or orbital prosthesis is attached (Figures 14.95 through 14.99).

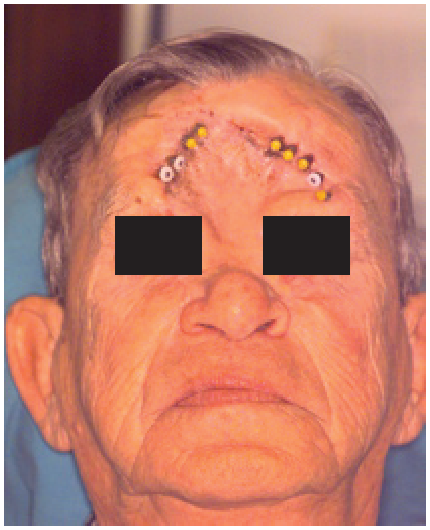


Figure 14.92 Frontal resection and implants.

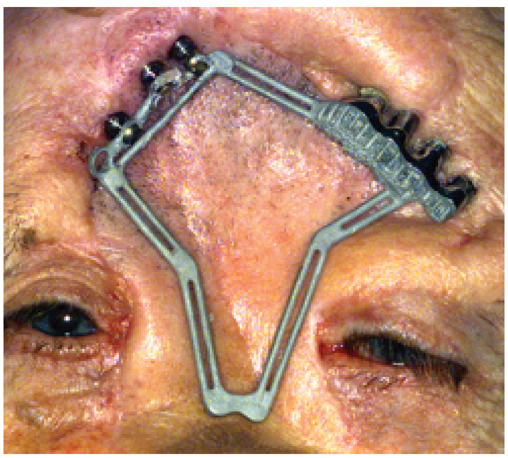


Figure 14.93 Super-structure.

Figure 14.94 Frontal prosthesis.

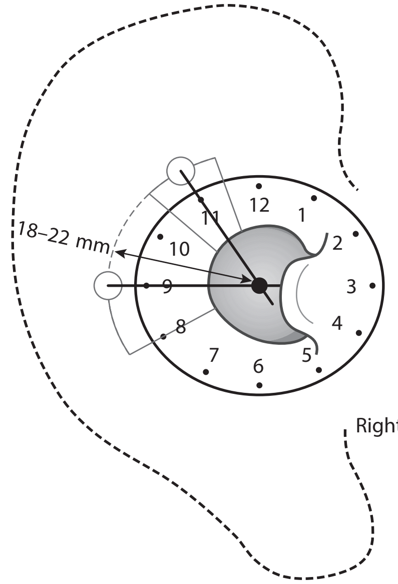


Figure 14.95 Implants positions.

Figure 14.96 Conformer in place.

ADVANCED DIGITAL TECHNOLOGY IN CRANIOFACIAL RECONSTRUCTION

Tumours of the craniofacial region can result in often grotesque facial disfigurement as a result of surgical intervention and subsequent radiotherapy. Treatment often alters the life-supporting functions of mastication, speech due to the excision of the bony and soft-tissue facial skeleton.

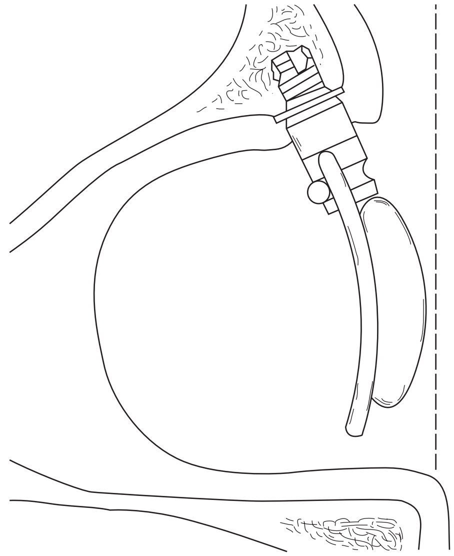
Conventional reconstructive techniques can be time consuming, relatively inaccurate and sometimes invasive. The advent of 3D CT greatly enhances diagnosis and

Figure 14.97 Auricular prosthesis.

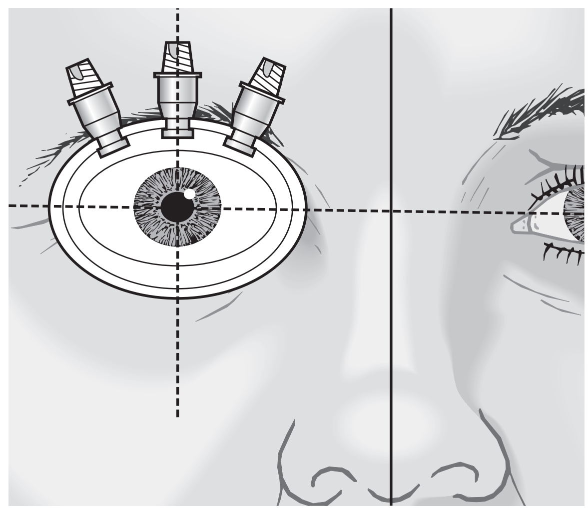
Figure 14.98 Orbital defect.

treatment planning of craniofacial reconstruction and its rehabilitation. This technology has been enhanced more recently with the advent of CT manipulation and virtual surgical planning. The use of this software can enhance reconstruction by reducing clinical time and is therefore cost effective, less invasive and more accurate.

The complexity of the surgery dictates the extent of the pre-operative planning and the reconstructive plan can be exported to a rapid prototyping platform, which further enhances the 3D platform to a tactile 3D model (Figures 14.100 through 14.102).



(a)



(b)

Figure 14.99 (a and b) Implant positions in the orbit.

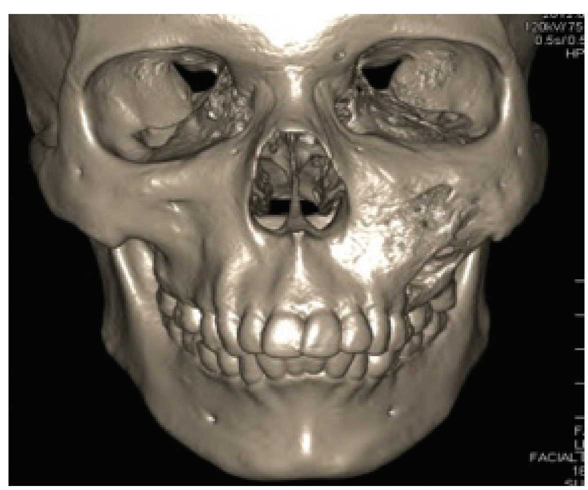


Figure 14.100 CAT scan of tumour.

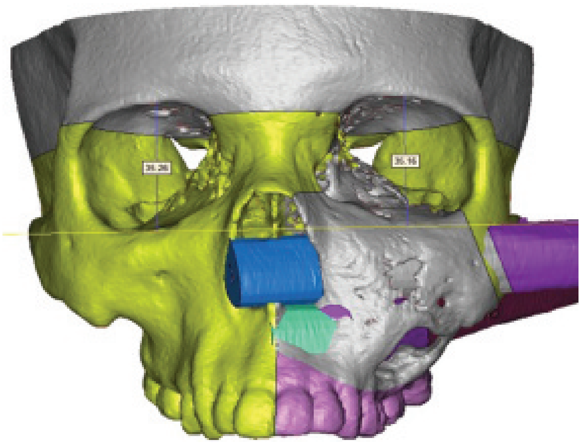


Figure 14.101 Computer model.

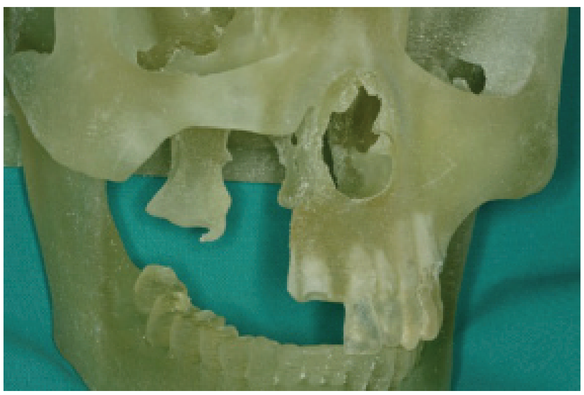


Figure 14.102 Stereolithographic model.

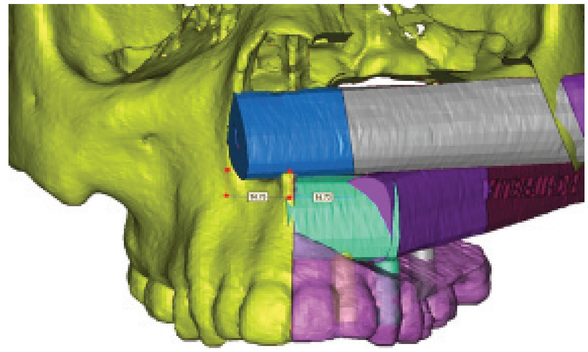


Figure 14.103 Digital fibula in position.

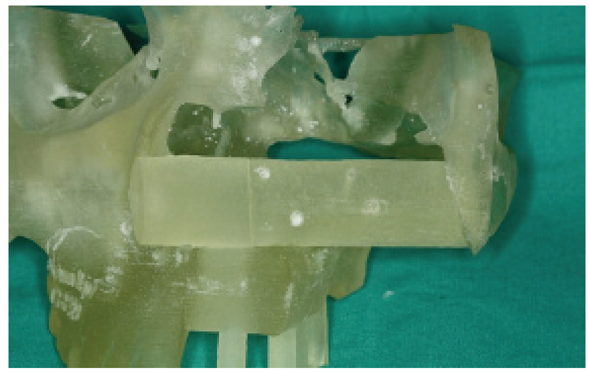


Figure 14.104 Model of fibula position.

Hemi-maxillectomy or total maxillectomy causes complex defects in the maxilla, the zygoma and palate, orbital floor, maxillary sinus, alveolar bone and mucosa. These defects can have severe functional and cosmetic consequences and resection, whether it is due to oncology or ablation has to adequately reconstruct and rehabilitate the patient both aesthetically and functionally.

The main aim of complex midface reconstruction should recreate facial aesthetic appearance and symmetry, improve mastication and to obliterate any communication between the orbit, oral cavity and nasopharynx. Defects have traditionally been managed using a large dental obturator prosthesis, which can be an excellent and definitive treatment for some patients. However, with the advent of microvascular free tissue transfer, rehabilitation of the maxilla and mandible has become possible with osseous free flaps, which allow for implant borne dentition.

Bone from numerous osseous donor sites, such as the scapula, radius, iliac crest, rib and fibula, has been used for reconstruction of maxillary defects. The free vascularized fibula flap has become the most popular because of its length and acceptance of dental implants.

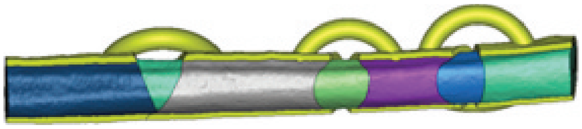
The use of virtual planning and rapid prototyping is increasingly popular in reconstructive surgery, particularly in complex anatomical reconstructions. Rapid prototyping facilitates the manufacture of 3D models and templates that allow the surgeon to plan the procedure before surgery, thereby closing the gap between pre-operative planning and surgical resection and rehabilitation. Medical CAT scan DICOM data is utilized to manufacture the stereolithographic templates, which help the surgeon to accurately plan the operative resection and subsequent rehabilitation (Figures 14.103 and 14.104).

Prior to surgery, a rapid prototyped stereolithographic model template is manufactured to help determine the planned lengths and angles of the fibula osteotomies, as well as the position and angulation of the dental implants, which are to be placed into the fibula (Figure 14.105).

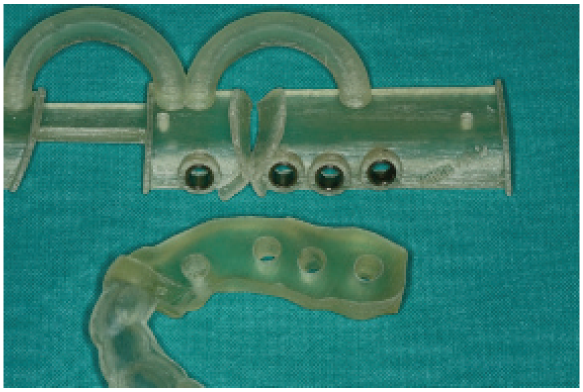
The 3D digital model allows for the fabrication of a 3D stereolithographic model, which also facilitates the pre-positioning and pre-bending of the pre-bent titanium bone plates. The pre-bent plates are then sterilized and this significantly reduces theatre time at time of surgery (Figures 14.106 and 14.107).

The surgical template was fixed to the fibula using osteosynthesis screws after which the dental implants were inserted into the fibula with the pedicled blood supply still attached (Figures 14.108 and 14.109).

An innovative designed implant (X-type Implant; Southern Implants™, Irene, South Africa) for insertion into the fibula is used and a restorative guide is used to correctly position the implants into their correct position (Figures 14.110 and 14.111).



(a)



(b)

Figure 14.105 (a and b) Digital fibula cutting guide and rapid prototyped drilling guide.

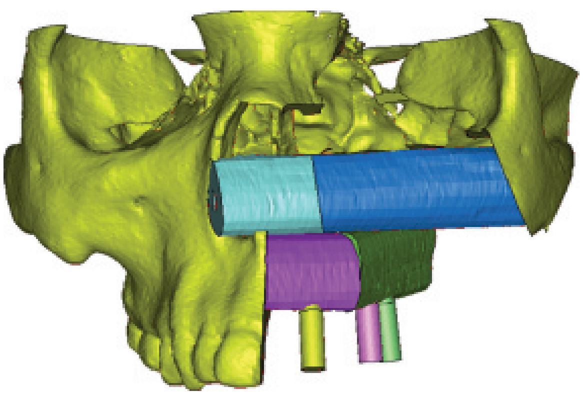


Figure 14.106 Digital implant positions.

Figure 14.107 Pre-bent plates on model.

The surgical template of the fibula assists and guides the surgeon with the insertion of dental implants, which are placed in the free fibula graft prior to resection and the planned osteotomies.

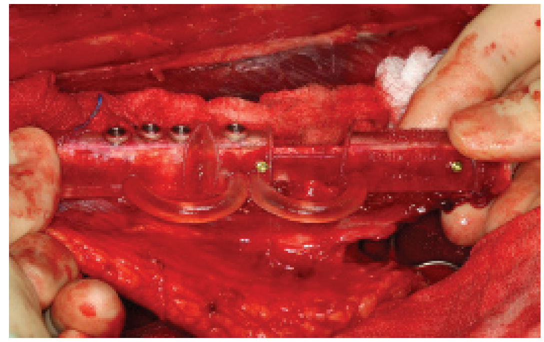


Figure 14.108 Cutting guide on fibula.

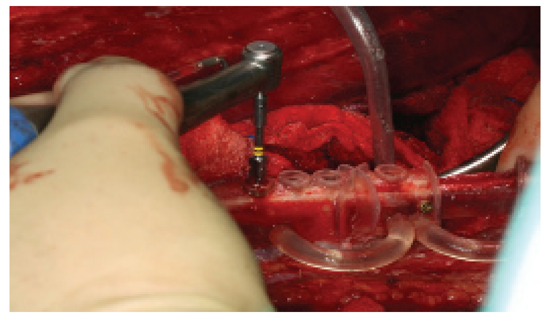


Figure 14.109 Implant osteotomies.

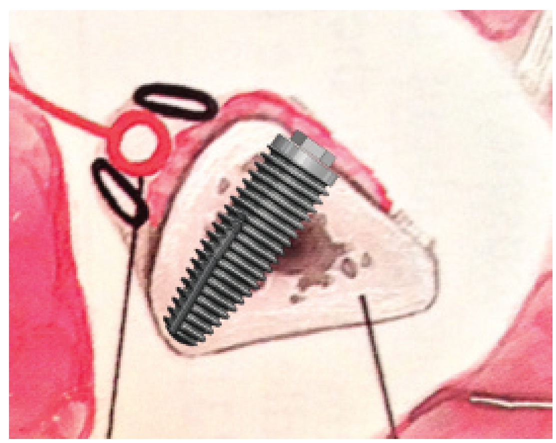


Figure 14.110 X-type implant inserted in fibula.

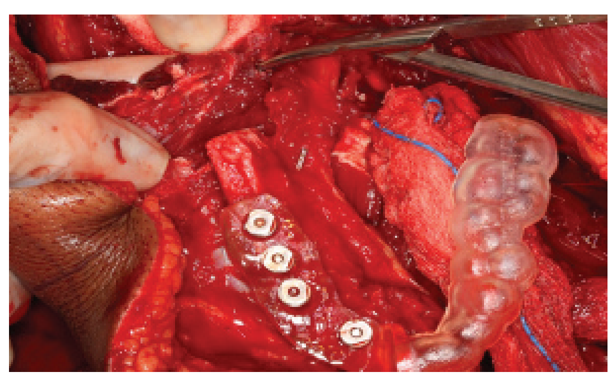


Figure 14.111 Positioning guide prior to pedicle division.

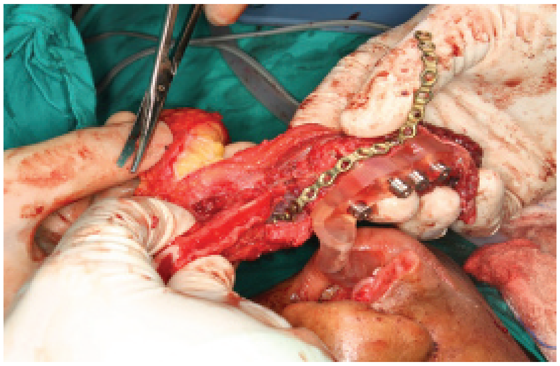


Figure 14.112 Fixed graft onto bone plate.

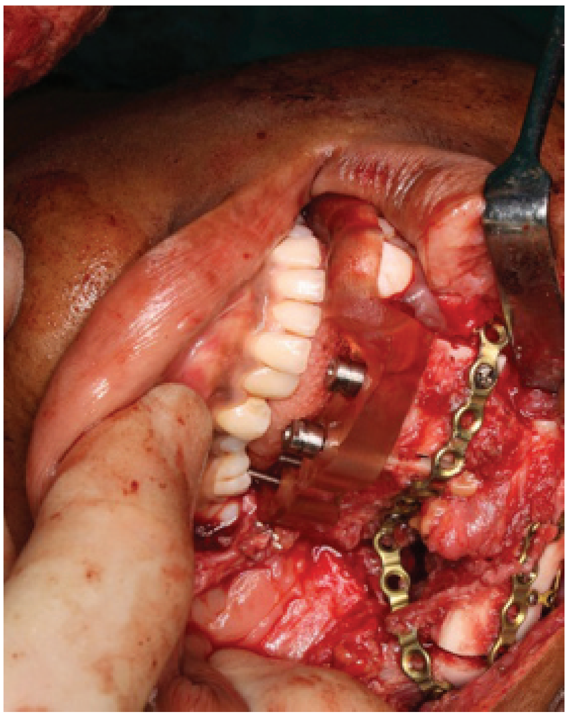


Figure 14.113 Vascularized fibula in situ.

Figure 14.114 Abutments in place.

Figure 14.115 Facial access sutured.

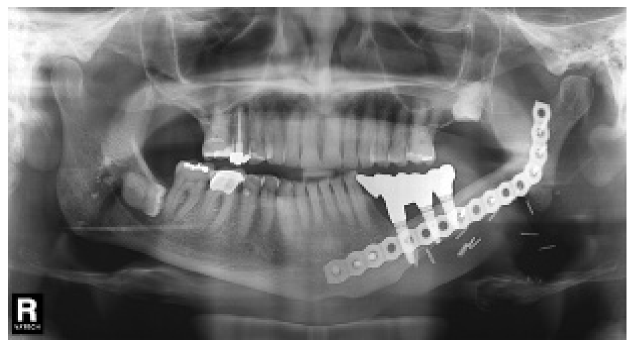


Figure 14.116 Restored implants in the fibula.

The osseomyocutaneous flap is then fixed to the pre-bent titanium reconstruction plate and placed in the exact pre-planned position at the recipient site and fixed with osteosynthesis screws (Figures 14.112 and 14.113).

The stereolithographic dental guides are then removed and abutments are placed into the implants. The closure of the surgical site is then affected and the patient transferred to the intensive care unit for post-operative monitoring (Figures 14.114 and 14.115).

After healing, the implants are exposed together with soft-tissue pre-prosthetic surgery to reduce the bulk of the skin paddles inside the oral cavity and the implants are restored using conventional implant-supported crown and bridgework (Figure 14.116).

In conclusion, virtual digital planning and rapid prototyping are a valuable and precise technique for large reconstructions of complex anatomical sites. Virtual planning and rapid prototyping provides a method to accurately evaluate the anatomy of a defect with optimized pre-surgical planning. The accurate pre-planning of bony osteotomies and optimized fit of the graft without further need for osseous adaption significantly reduces surgical time and also produces a highly predictable outcome of surgery.

Top tips

- Stereolithographic models are essential for planning.
- With implant retained prostheses, implants are often a better option than surgical reconstruction.

ACKNOWLEDGEMENT

The authors wish to acknowledge the contribution made by Southern Implants™ in the development of the zygomatic oncology and x-type implants.

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15

Tissue engineering

MILLER H SMITH, KENJI IZUMI and STEPHEN E FEINBERG

CONTENTS

INTRODUCTION

In order for oral and maxillofacial surgery to advance as a specialty, we must continuously investigate new treatment options. Over the past quarter of a century, the scope of tissue engineering has exploded in an attempt to provide solutions to improve hard and soft-tissue healing. Restoring three-dimensional (3D) form and function is of utmost importance through reconstruction of tissue defects, and tissue-engineered products can minimize morbidity associated with the harvest of autogenous soft and hard tissue grafts. Materials and techniques continue to evolve and many are being investigated to be able to provide unique alternatives to the oral and maxillofacial surgeon in the near future. Soft-tissue constructs attempt to decrease scar tissue formation and maximize our innate healing potential. Recently, muco-cutaneous (M/C) grafts have been successfully fabricated for lip reconstruction. Regeneration of osseous, and cartilagenous tissues require the use of engineered scaffold constructs fabricated from various materials with the combination of numerous biological factors. In addition, investigation into regeneration of craniomaxillofacial structures is on the rise, and some have even evaluated prefabricated free vascularized hard tissue grafts for use in maxillofacial reconstruction.

INDICATIONS

Tissue engineering is indicated in the following:

1. Preprosthetic surgery
2. Following pathological resection
3. Following trauma
4. Developmental deformities

SOFT-TISSUE RECONSTRUCTION

Principles and justification

Oral mucosa and skin are the most common autogenous soft-tissue grafts used for preprosthetic surgery and resurfacing of oral mucosal defects. Both require a second surgical donor site resulting in significant patient morbidity. Oral mucosa is limited in supply while the functional and aesthetic outcomes of skin grafts are often unfavourable. Skin and oral mucosa substitutes prevent donor site morbidity, provide more therapeutic options and accomplish better outcomes than conventional therapies in reconstructive surgery. One method of creating a tissue-engineered soft-tissue substitute is through the manufacture of an ex vivo produced oral mucosa equivalent (EVPOME) in which an epithelial layer of autogeneous

oral keratinocytes is developed and grown on AlloDerm® (LifeCell, Branchburg, New Jersey), an acellular, non-immunogenic, human cadaver dermis (Figures 15.1 and 15.2). AlloDerm® confers excellent handling characteristics resulting in a supple nature to the grafts, and is a tissue product well established in the field of oral and maxillofacial surgery. The EVPOME graft is then used for reconstruction of the desired soft-tissue defect by suturing it in place over a recipient bed with adequate blood perfusion to allow rapid vascularization of the graft to occur. EVPOME is utilized as a full-thickness oral mucosa substitute and has characteristics of keratinization identical to that of native oral mucosa (Figure 15.3). As an advanced application of this EVPOME fabrication technique, we developed another technology growing human oral and skin keratinocytes into a 3D construct to form a M/C junction containing stratified oral mucosa and stratified skin on the same AlloDerm® (Figure 15.4).

Ideally, a number of principles must be adhered for proper success of a soft-tissue graft:

1. The recipient bed must be vascularized.
2. The graft must not be placed on bare cortical bone.
3. Stabilization and immobilization allows for vessel inosculation from underlying capillary network.
4. Close adaptation to the recipient bed is essential.
5. Bolsters or surgical stents acting as a pressure dressing must be used to ensure hematoma formation is avoided under the graft.

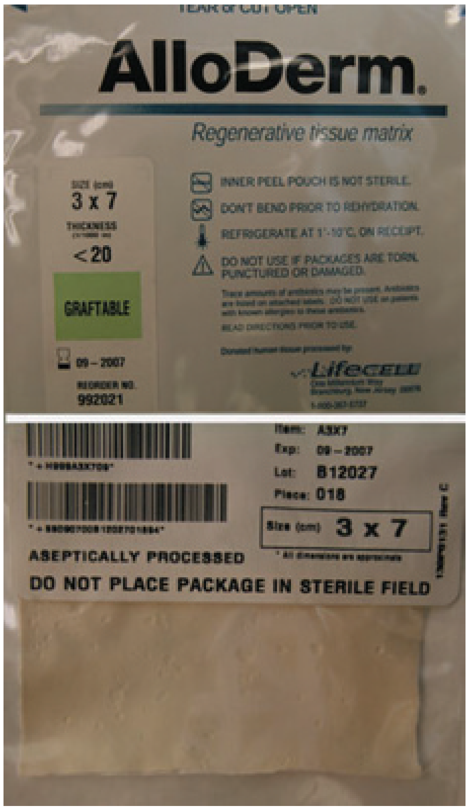


Figure 15.1 Package of AlloDerm, 3 cm × 7 cm in size (top); inner pouch (bottom). The author prefers the thinnest piece (0.009–0.013 inches, 0.22–0.33 mm).

PROCEDURE

The patient is usually scheduled four weeks prior to the desired reconstructive surgery in order to harvest a biopsy of the oral mucosa. A tissue punch provides adequate number of compatible keratinocytes to manufacture EVPOME grafts prior to transplantation, while causing minimal morbidity. Palatal tissue provides a keratinized mucosa equivalent, while the retromolar pad or buccal mucosa provides non-keratinized mucosa equivalent. The patient is anesthetized using local infiltration techniques. A small 4–6-mm split thickness punch biopsy is performed to the level of the dermis (Figure 15.5). At the palate, local haemostasis is obtained with pressure, and the wound is dressed with a haemostatic collagen material stabilized with a figure-eight suture. At the retromolar area or buccal mucosa, the wound is closed primarily. The harvested tissue is transferred into a culture medium and transported into the laboratory.

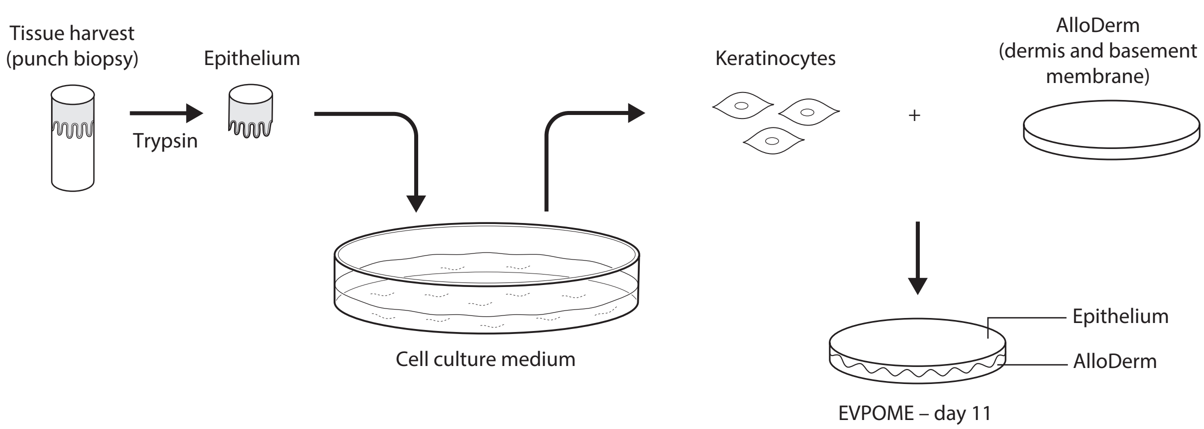


Figure 15.2 Tissue punch is used to isolate keratinocytes which are then cultured and seeded onto a basement membrane of AlloDerm.

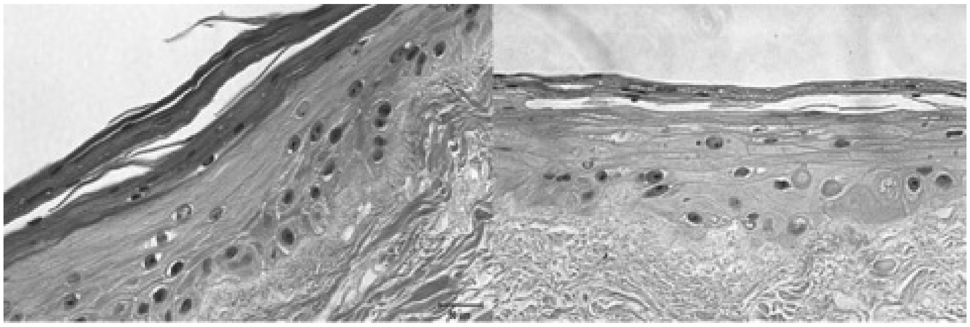


Figure 15.3 Haematoxylin and eosin stains of ex vivo produced oral mucosa equivalent graft at days 11 and 18, demonstrating integration of keratinized layer overlying AlloDerm.

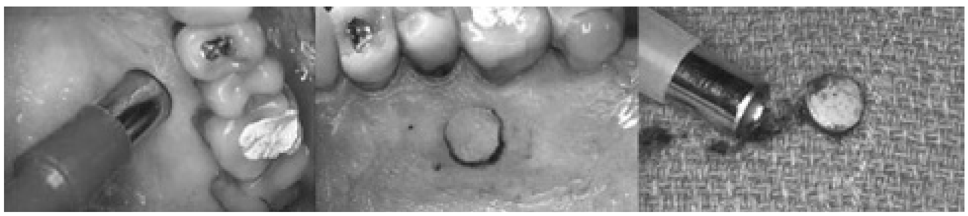


Figure 15.4 Tissue punch for tissue harvest from hard palate for isolation and growth of keratinocytes.

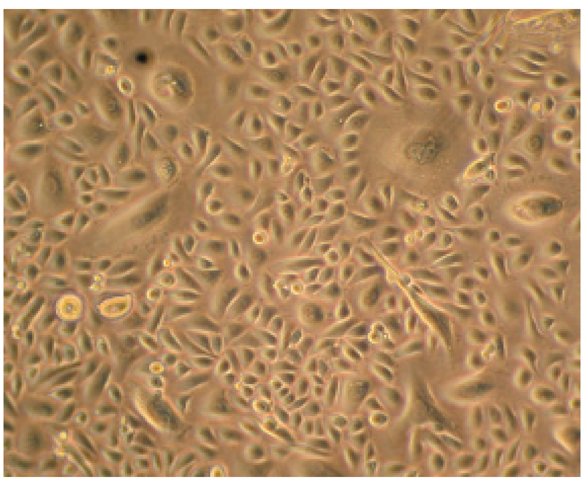


Figure 15.5 Oral mucosa keratinocytes in culture are poised to be seeded on to AlloDerm.

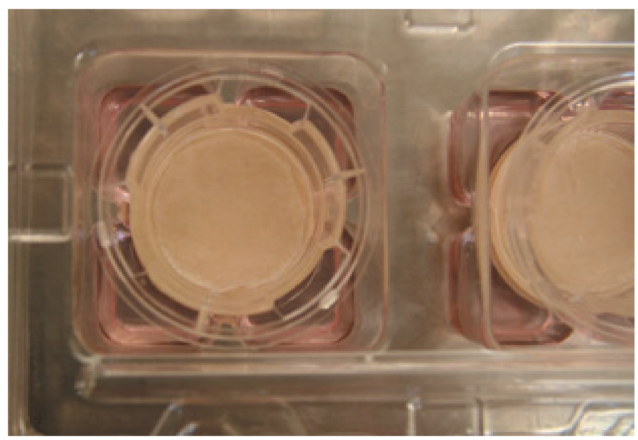


Figure 15.6 Rehydrated AlloDerm is soaked in human type IV collagen ensuring that the epidermal side (retained intact basement membrane) is positioned uppermost. A composite of oral keratinocytes and AlloDerm is then submerged in culture and transferred to an air–liquid interface.

The manufacturing and culturing procedures of the EVPOME have been described in detail elsewhere. Briefly, oral keratinocytes are dissociated by soaking the harvested biopsy tissue in 0.04% trypsin solution. The cells are grown in a culture medium free of bovine serum, mouse feeder-cells and pituitary extracts. The lack of foreign xenogenic cells avoids any cross contamination or immunization. Following growth of a sufficient number of keratinocytes over 2 weeks (Figure 15.6), cells are seeded onto pieces of type IV collagen presoaked AlloDerm® (cells are seeded on the roughened basement membrane side). For the first 4 days, a composite of keratinocytes and AlloDerm® is incubated in a submerged culture. For the next 7 days, the composite is raised at an air-liquid interface culture. Upon reaching day 11 after seeding the dermis with keratinocytes, the EVPOME grafts are ready to transplant (Figure 15.7).

Preparation of the recipient bed is created through conventional surgical procedures such as vestibuloplasty and tumour excision. These basic procedures are found in Chapters 10 and 19, respectively. Vestibuloplasty is often used to create an appropriate environment for the placement of implants or denture support in case of insufficient vestibular depth and/or complete loss of a keratinized

Figure 15.7 Thick unattached oral mucosa overlying posterior alveolar ridge is an impediment for dental implant success and must be corrected prior to endosseous implant placement.

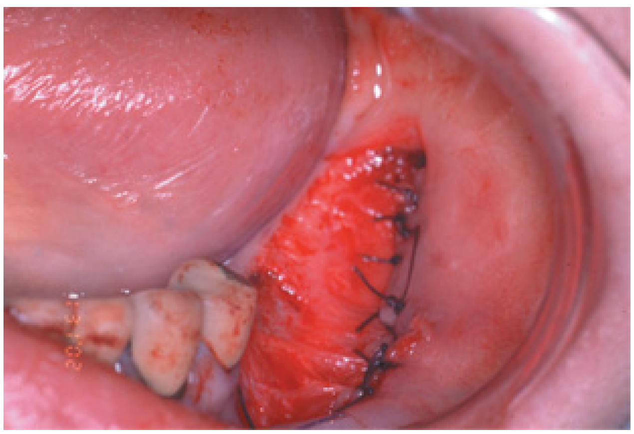


Figure 15.8 Split thickness supraperiosteal dissection to the desired vestibular depth with the leading margin tacked to the underlying periosteum with sutures.

(attached, immobile) gingival (Figure 15.8). A supraperiosteal split thickness dissection is made with a scalpel or metzenbaum scissors. The tissue is then pushed apically to the desired height of vestibule and then sutured to the underlying periosteum (Figure 15.9).

For cases of tumour excision, such as the lateral border of the tongue, it is common to place a soft-tissue graft for suitable healing. Appropriate margins surrounding the tumour are inked (Figure 15.10), and tissue is incised using electrocautery. Haemostasis is achieved most commonly using electrocoagulation and rarely with ligation to maximize preservation of the vascularity of the recipient site (Figure 15.11).

The EVPOME is then trimmed to the desired size and shape using a sharp no. 10 blade scalpel rotating over the belly of the blade without pulling or dragging the blade, to avoid disruption of the keratinocyte cell layer. In the process of handling the grafts for reshaping and suturing, one should be careful to avoid touching and rubbing the EVPOME surface (Figure 15.12). Only blot dry the graft with sterile cotton gauze being as atraumatic as possible,

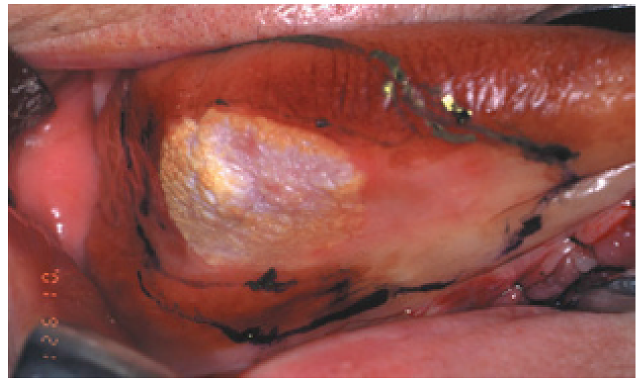


Figure 15.9 Tumour to the right lateral border of the tongue (squamous cell carcinoma T2N0M0) with inked margins. (From Wakita M et al., *Oral Histology and Embryology*, Ishiyaku Publishers, Tokyo, 2006. With permission.)

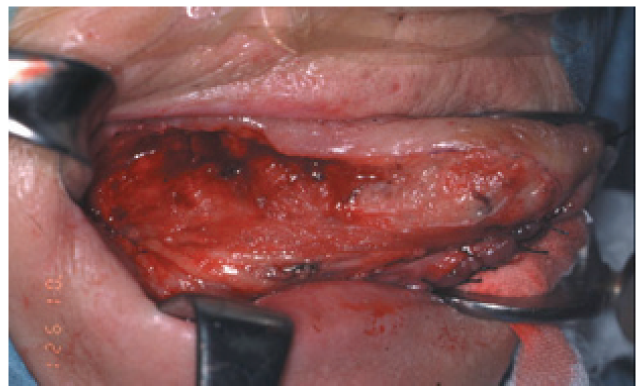


Figure 15.10 Wide local excision using electrocautery. (From Wakita M et al., *Oral Histology and Embryology*, Ishiyaku Publishers, Tokyo, 2006. With permission.)

Figure 15.11 Ex vivo produced oral mucosa equivalent graft prior to transplantation.

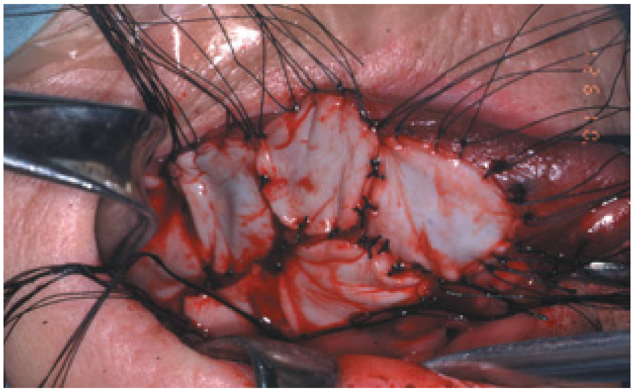


Figure 15.12 Six pieces of ex vivo produced oral mucosa equivalent are sutured over the wound bed in place. (From Wakita M et al., *Oral Histology and Embryology*, Ishiyaku Publishers, Tokyo, 2006. With permission.)

Figure 15.13 A bolster of antibiotics-soaked gauze is used to apply pressure to the ex vivo produced oral mucosa equivalent grafts for prevention of haematoma formation. (From Wakita M et al., *Oral Histology and Embryology*, Ishiyaku Publishers, Tokyo, 2006. With permission.)

avoiding any wiping motion. EVPOME grafts are placed with the Alloderm® side down over the recipient bed and fixed in place to the surrounding mucosa with 4-0 silk on a cutting needle. The graft is secured within the defect using interrupted sutures cut short to the knot. Long uncut marginal sutures opposing one another are tied over a bolster of antibiotic-soaked gauze to apply pressure to the defect to minimize dead space and hematoma formation (Figures 15.13 through 15.16). For vestibuloplasties, a rigid surgical stent can be created pre-operatively, and secured in place intraorally with miniscrews or circumosseous wires (Figure 15.17). The gauze bolster and sutures are removed at post-op day 7 after grafting. The underlying EVPOME grafts possess a characteristic red hue indicative of early revascularization (Figure 15.18). After a period of 4 months, the graft will have integrated and will possess adequate keratinization to allow for implant placement (Figure 15.19).

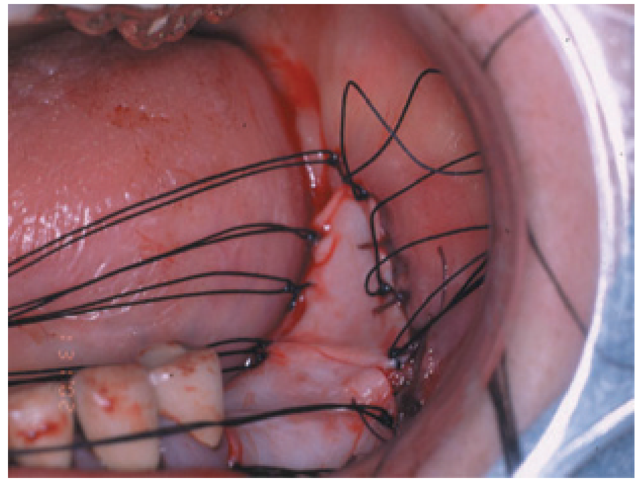


Figure 15.14 Two pieces of ex vivo produced oral mucosa equivalent configurated and sutured in place to the left posterior alveolar ridge.

Figure 15.15 Bolster secured using opposing sutures to stabilize the graft.

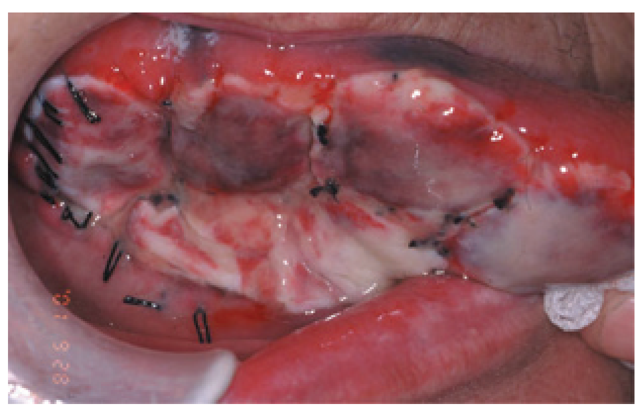


Figure 15.16 Healing ex vivo produced oral mucosa equivalent grafts 7 days following placement demonstrating early vascularization from the underlying tissue.

Figure 15.17 Conversely, grafts can be secured with a surgical resin stent lined with tissue conditioner to avoid pressure areas.

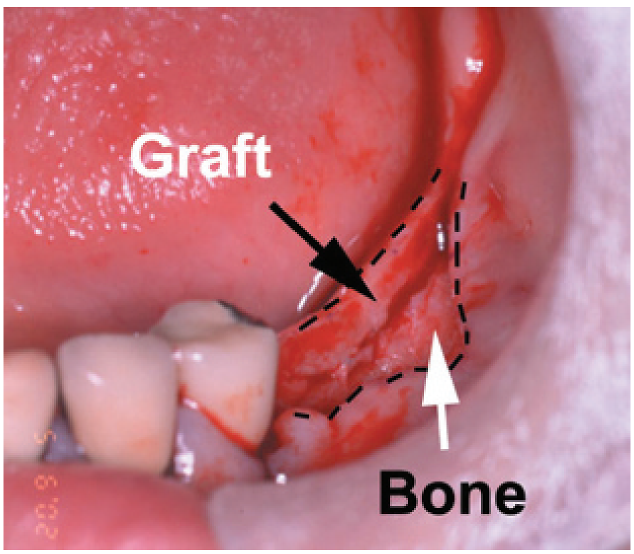


Figure 15.18 Incision made 4 months post-operatively revealing healthy attached gingiva acceptable for implant placement.

M/C GRAFTS FOR LIP RECONSTRUCTION

A complex structure of the face to reconstruct after surgery or trauma/avulsion is the lips because they represent a composite tissue of mucosa, skin and muscles. Since the neuromuscular control of normal lip structures is required for activities of eating, drinking, talking and social gestures, significant loss of lips is a functional and aesthetic concern for injured individuals. The fabrication of a M/C tissue engineered construct in vitro has been recently successful in our research laboratory (Figure 15.4). The approach presented in the tissue-engineered lips will have several advantages for the reconstruction of craniofacial

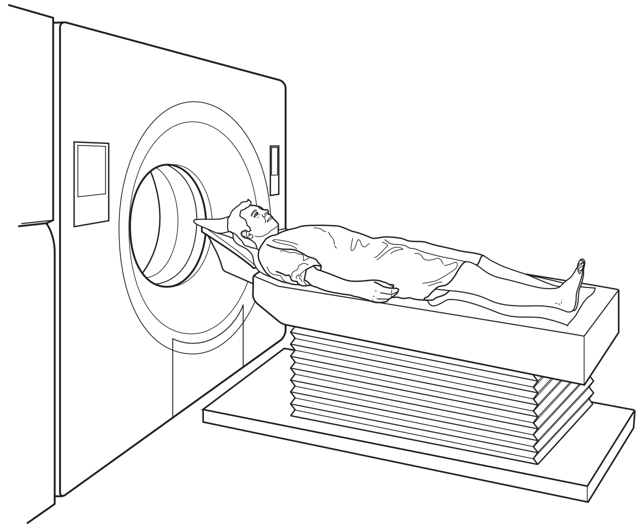


Figure 15.19 Patient is imaged using computed tomography or magnetic resonance imaging.

soft-tissue injuries. In particular, the source of the cells to develop the 3D lip constructs will come from small punch biopsies from the oral mucosa and skin of the patient, thus making the construct autologous. This 3D lip construct contains all functional areas of the epithelium of the human lip and can be used as the basis for the fabrication of vascularized prelaminated flaps for full lip reconstruction or for repair of the lips when both the oral and epidermal areas require tissue replacement. Prelamination designates a reconstructive process whereby a 3D structure is built at a remote site by laminating different layers of components, epithelium, dermis and muscle, as composite grafts into a reliable existing axial vascular bed, allowing the structure 2–3 weeks to mature before transferring the unit en bloc to the defect. In addition, this technique can be extended to other anatomic areas for the repair of tissues where a M/C junction is present, including the nares, eyelids and urogenital system with the surgical procedures to create prefabricated flaps with their own blood supply.

HARD TISSUE RECONSTRUCTION

Principles and justification

The underlying hard tissues offer the framework for overlying facial aesthetics, as defects in osseous and cartilaginous tissues are visibly portrayed through the soft tissues. Classically, significant morbidity and deformity is traded in a distant donor area for reconstruction of craniofacial structures. Allogeneic grafts are available; however, in order to achieve minimal immunologic response, all cellular tissues are removed reducing the potential for reliable integration. Lastly, alloplastic materials are at risk for foreign body reaction, with significant inflammation and increased risk of infection. Tissue-engineered scaffolds have been created to capitalize on a patient's innate

healing response while adding specific factors at the local site to attempt to improve hard tissue regeneration. Tissue engineering has explored a number of materials for creation of scaffolds including polymers, ceramics and composites. Polymers (polylactic acid, polyglycolic acid, polycaprolactone, polypropylene fumarate) have variable properties and offer reliable biodegradation. More permanent ceramics (hydroxyapetite, tricalcium phosphate) can be used alone, but are frequently combined with polymers in composite grafts. Composites can also include biofactors such as purified concentrated growth factors, transduced cells with various viral vectors, and autogenous bone marrow cells.

Ideally, a number of principles must be adhered to prior to the fabrication of any tissue-engineered scaffold for replacement into osseous defects.

1. Replace complex 3D defects
2. Biocompatible with minimal inflammatory response
3. Offer functionality and immediate load bearing
4. Bioresorbable, allowing native structures to assume load bearing as they degrade
5. Mechanical properties similar to native tissues
6. Prevent ingrowth of harmful fibrous tissues
7. Delivery of biofactors
    a. Inserted at time of fabrication
    b. Inserted at time of surgery
    c. From adjacent native bone

PROCEDURE

The surgeon will often obtain pre-operative imaging to determine the extent of the current or surgically created defect. CT, both conventional and cone beam, as well as magnetic resonance imaging can be used for this purpose depending on the structures being evaluated (Figure 15.4). The patient's data set is captured on file and a 3D image is rendered for treatment planning using a variety of image processing software (Figure 15.20). Depending on the location, shape and size of the defect, an ideal scaffold template contour can be created de novo electronically by virtual design, or by reversing the data from the patient's normal contralateral side (Figures 15.21 and 15.22). Image software includes

Figure 15.20 Using image processing software, data set reconstructed into three-dimensional image for treatment planning.

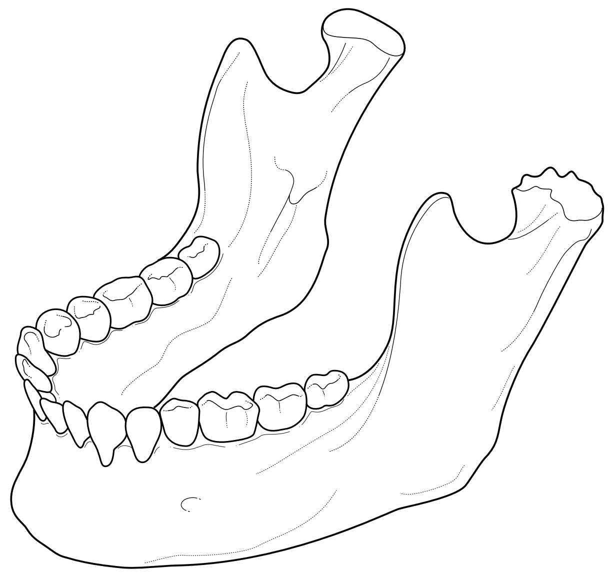


Figure 15.21 Degenerative joint disease of the left mandibular condyle.

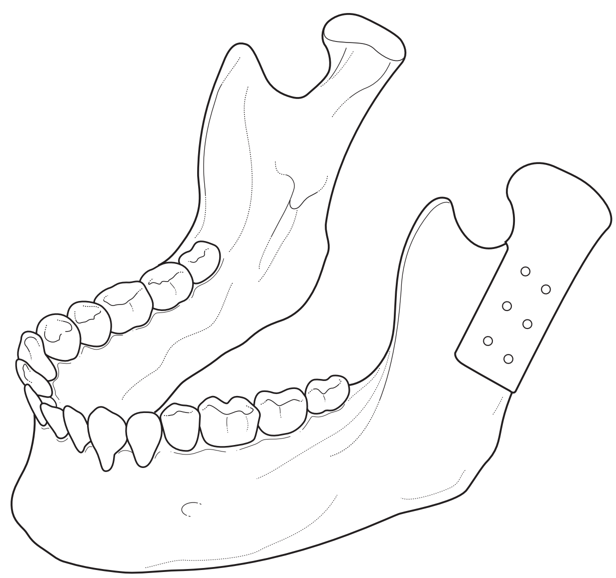


Figure 15.22 Using image-based design, mandibular condyle can be created to specific dimensions based on the treatment plan or replicated from the normal contralateral condyle. The remainder of the scaffold developed with well-adapted overlying sleeve to secure the condyle in place.

ANALYZE (www.analyzedirect.com), PV-WAVE (www.ittvis.com) and MATLAB® (www.mathworks.com). Once the template is created through a mapping data set, the microstructure of the scaffold is then created with a porous architecture database. Various microstructures can be applied based on the material used and mechanical properties desired to attempt to promote growth of either cartilaginous or osseous tissues. Mathematically designed interconnecting porous cylinders and interconnecting porous spheres are two examples (Figure 15.23) where effective modulus (strength) and porosity are inversely proportional (Figure 15.24). Additionally, shells without internal microstructure can offer delivery of well-contained bone marrow directly to the defect while minimizing load-bearing capabilities. Portions of the scaffold are extended beyond the defect and dilated over adjacent native bone for securing the scaffold once implanted. A scaffold is then fabricated using solid free-form fabrication techniques such as fused deposition modelling, stereolithography or selective laser sintering (SLS) (Figure 15.25). SLS is a rapid prototyping method that offers layer-by-layer fusion of particles to create complex geometric shapes, as well as intricate microstuctures with porous spaces that can be smaller than 1 mm. Virus-transfected cells and biofactors can be directly linked to the scaffold structure using various culture media and techniques described elsewhere (Figure 15.26). Conversely, at the

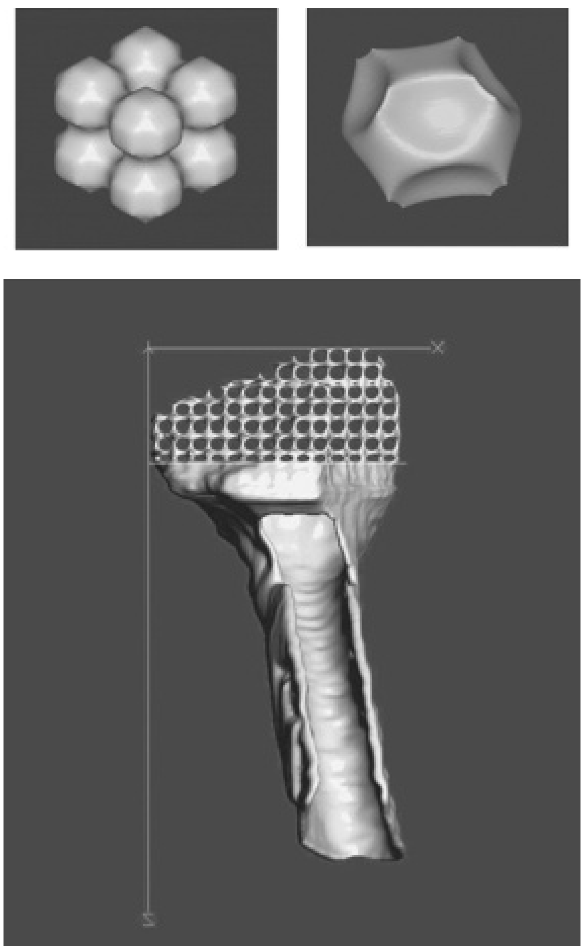


Figure 15.23 Sphere (upper left) and cylinder (upper right) unit cells can be used to create microstructure to portions of the scaffold.

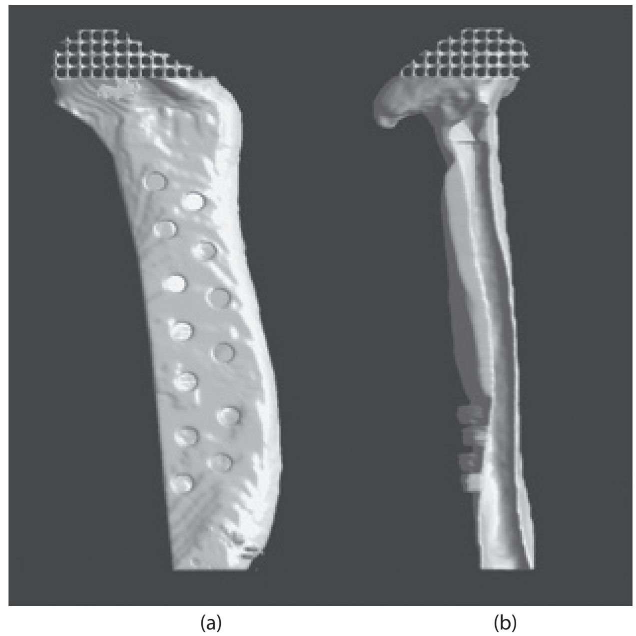


Figure 15.24 Scaffolds can be created to replace complex three-dimensional shapes with localized areas of microstructure and an attached sleeve to secure to native bone.

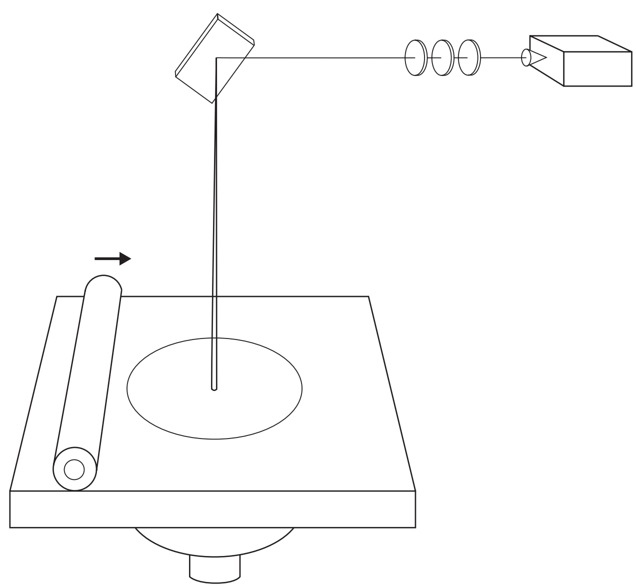


Figure 15.25 Selective laser sintering.

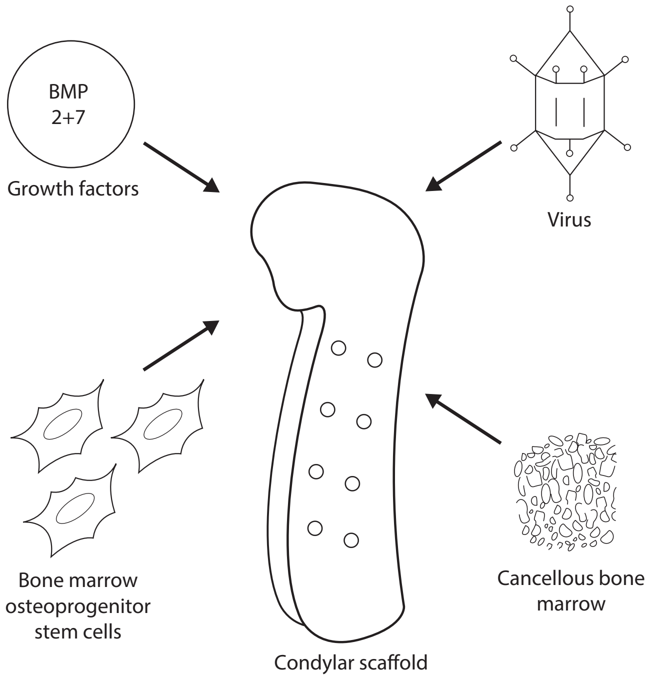


Figure 15.26 Various biologics can be used for creation of composite scaffolds. Concentrated recombinant bone morphogenetic proteins, viral transfected cells, bone marrow osteoprogenitor stem cells and harvested cancellous bone marrow are some examples.

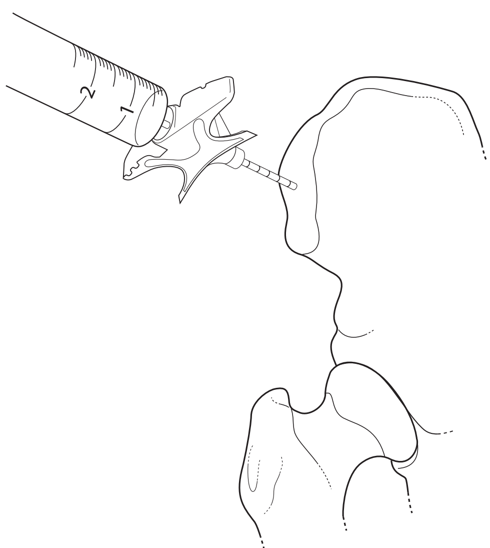


Figure 15.27 Bone marrow is aspirated from the anterior iliac crest to harvest osteoprogenitor stem cells.

time of surgery, bone marrow stromal cells can be harvested and isolated from aspirates and inserted directly into the scaffold immediately prior to implantation (Figure 15.27).

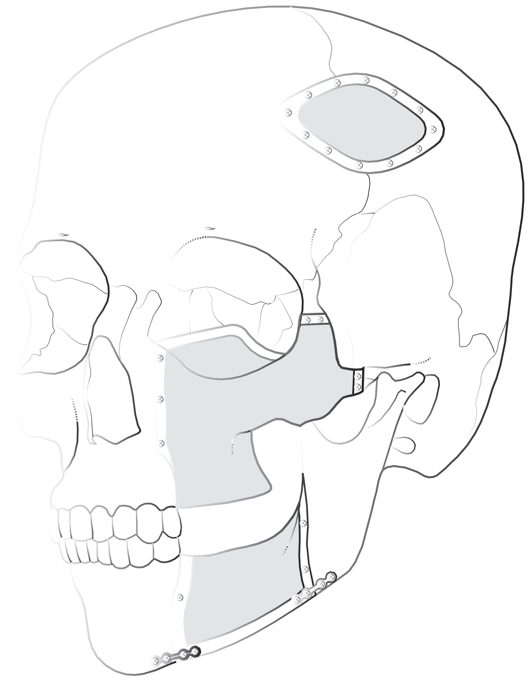


Figure 15.28 Scaffolds can be created to correct complex geometric shapes of the craniomaxillofacial complex.

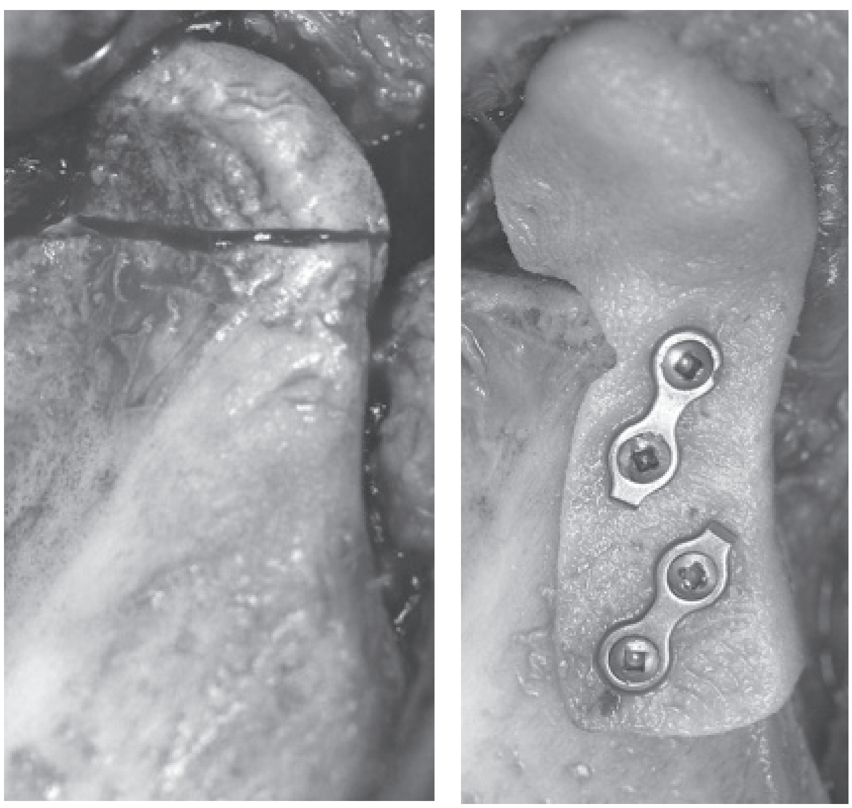
Specific structures that have been attempted for regeneration include mandibular condyles, orbital rims and segmental defects in the mandible (Figure 15.28). The scaffolds themselves are of varying size and shape to fill the defect as precisely as possible. Based on the area of interest, standard surgical techniques are used as discussed in Section III. Wide exposure of the bone and cartilaginous tissues is performed through elevation and retraction of subperiosteal tissues, being careful to avoid excessive trauma to the overlying mucosa and periosteum. In cases of trauma or developmental deformity, the defect is isolated, and an acceptable tissue bed for placement of the scaffold is created in order to ensure appropriate primary closure of the tissues. Conversely, in cases of pathological resection, presurgical evaluation determines approximate margins which may change at the time of surgery depending on the specimen resected. The scaffold may need to be trimmed partially in order to fit into the defect precisely. Bone marrow can be harvested from the hip either by conventional exposure as described in Chapter 13, or using a microaspiration device. Bone marrow stromal cells can be isolated using a microfluidic device, or cancellous marrow spicules can be crushed with mortar and pestle, and cells or small cancellous fragments can be injected within the scaffold porosities (Figure 15.29). Miniplates and screws are used to secure the scaffold to the native bone to ensure four-point stabilization. In order to advance the tissues over the scaffold to obtain primary closure, the periosteum is cross

Figure 15.29 Cancellous bone marrow, harvested via a conventional surgical approach, is packed into the hollow shell of a mandibular condylar–ramus scaffold.

hatched using a scalpel (Figure 15.30). Metzenbaum scissors can also be used to dissect the tissues for larger advancements. The overlying tissues are closed primarily in layers using interrupted sutures. Horizontal mattress sutures may be used to release tension if tissues are tight to close.

Top tips

- A multidisciplinary team approach utilizing the services of oral and maxillofacial surgeons, biomedical and mechanical engineers, radiologists and adjunct scientists is necessary for proper investigation and fabrication of tissue engineered materials.
- Soft-tissue defects have the potential to be reconstructed with minimal morbidity with the use of combination grafts.
- Computer-engineered scaffolds have the ability to be combined with various biological components to attempt to improve regeneration of osseous and cartilaginous tissues.
- Further research is imperative for continued advances.



(a) (b)

Figure 15.30 In animal models, following condylectomy, a well-adapted condylar–ramus scaffold is secured in place using miniplates and screws, allowing for immediate function.

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SECTION III

SURGICAL TECHNIQUES

16

Emergency procedures

DAVID W MACPHERSON and CLIVE A PRATT

CONTENTS

INTRODUCTION

There are relatively few 'life- or limb-threatening' emergencies in oral and maxillofacial surgery (OMFS) and as a result wide experience of dealing with them is relatively sparse. This chapter is aimed at giving a 'hands-on' text of how to assess and perform these procedures. Because OMFS is a very specialized field, physicians from other specialties are likely to have even less experience in dealing with these problems and it is therefore essential that OMFS surgeons should be trained and competent to deal with these emergencies should they occur.

SURGICAL AIRWAY

Emergency surgical airway

Indications

The indications for an emergency surgical airway are failure to provide a definitive airway by either an oro- or nasotracheal approach. A disrupted airway would indicate maxillofacial trauma, while an obstructed airway would indicate the presence of a foreign body. This may be either as a result of the airway being disrupted or obstructed. Severe maxillofacial trauma, with significant disruption of the midface anatomy and associated profuse haemorrhage occasionally may make standard endotracheal intubation impossible, even by an experienced anaesthetist. If it is impossible to oxygenate the patient and protect the airway by other means, then an emergency surgical airway must be performed. All procedures described should be performed using universal precautions.

There are only two emergency surgical airways procedures, which are as follows:

1. Needle cricothyroidotomy
2. Surgical cricothyroidotomy

In children, the same procedures must be carried out, using the same techniques. Emergency tracheostomy is fraught with the same dangers and difficulties in children as in adults and needle and surgical cricothyroidotomies are quicker, more straightforward and therefore less risky procedures.

NEEDLE CRICOTHYROIDOTOMY

Needle cricothyroidotomy is performed as an absolute emergency on a patient dying from hypoxia and is carried out when oxygenation and protection of the airway is failing by conventional means.

If the patient is in the resuscitation room, with cervical collar, sandbags and tapes to immobilize the cervical spine, it is easier to carry out this procedure if these are removed and an assistant performs in-line cervical immobilization supporting the head.

Equipment needed

- Alcohol wipe
- 12–14G Venflon (+ spare)
- 10-mL syringe
- Connecting tube with Y-connector
- Oxygen source, 12–15 L/min

The cricothyroid membrane is identified by finding the superior end of the thyroid cartilage (Adam's apple) and sliding down the thyroid cartilage in the midline. The finger drops in to the cricothyroid membrane. Confirmation that this is the cricothyroid membrane is made by carrying on down to the hard cricoid cartilage (Figure 16.1).

Unfortunately, if there is any risk of cervical spine injury the neck must not be extended.

Wipe the skin with an alcohol wipe; attach a 10-mL syringe, with 1 mL of air in it, to the large-bore (12–14G) venflon and pass it through the cricothyroid membrane, aiming 45° inferiorly (Figure 16.2). There is a 'give' as the needle goes through the membrane, which is quite superficial. Eject the air and skin-plug from the syringe and aspirate the syringe. Getting air back shows the needle must be in the trachea. Slide the venflon in, sliding out the trocar – just like putting a venflon into a vein.

Technique

1. In-line immobilization of head by assistant
2. Universal precautions
3. Identify cricothyroid membrane
4. Alcohol wipe
5. Immobilize trachea between finger and thumb
6. 12G venflon with 10-mL syringe with 1 mL of air in it
7. Insert the needle in midline aiming 45° down the trachea
8. Eject air (+plug of skin) from syringe and aspirate
9. Remove trocar, connect to oxygen supply at 15 mL/min
10. Y-connector (or hole in tube) 1 second on, 4 seconds off
11. Monitor oxygen saturations
12. Prepare for surgical cricothyroidotomy

The connecting tube must have a Luer-type lock to attach to the venflon at one end, a Y-connector (or just cut a hole in the tubing) in the middle and a connector at the other end to attach to the oxygen cylinder or wall oxygen supply. The oxygen should be running at 12–15 L/min. Put a finger over the hole in the tubing in a ratio of 1 second on and 4 seconds off.

Jet insufflation via needle cricothyroidotomy can provide adequate oxygenation but unfortunately does not enable sufficient ventilation and there will therefore be a gradual rise in the pCO_2. It also does not protect the airway. Although theoretically a needle cricothyroidotomy with jet insufflation may give 30–40 minutes before the

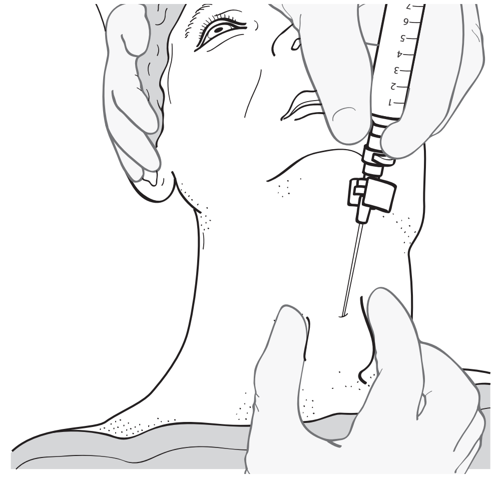


Figure 16.1 Needle cricothyroidotomy. Insertion of large-bore venflon at 45° caudally, in the midline, into the trachea. Inline immobilization of cervical spine by assistant.

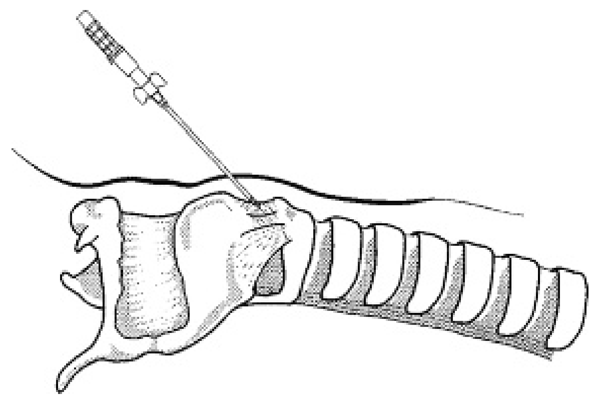


Figure 16.2 Jet insufflation of oxygen via a needle cricothyroidotomy.

pCO_2 rises to a critical level, it should only be looked upon as a very temporary (life-saving) measure before conversion to a surgical cricothyroidotomy.

This may enable time for a more experienced surgeon to arrive, but the time should anyway be spent preparing the necessary equipment.

In the case of a patient with severe maxillofacial trauma and a head (brain) injury, management of the following must be aimed at

1. Preventing any rise in pCO_2 which would exacerbate the brain injury
2. Protecting the airway from the associated haemorrhage

Surgical cricothyroidotomy

As soon as the oxygen saturation starts to rise following the needle cricothyroidotomy, confirming that oxygen is reaching the lungs, equipment must be collected

to convert this to a surgical cricothyroidotomy, with an inflated cuffed tube protecting the airway.

Local anaesthetic with vasoconstrictor (lidocaine 2% with adrenaline 1:100,000) should be infiltrated around the area so that this can be working while the necessary equipment is gathered (Figure 16.3) and an experienced surgeon is called.

Equipment needed

1. Local anaesthetic – lidocaine 2% + adrenaline 1:100,000
2. Scalpel with No. 11 blade
3. Tracheal dilator – or curved artery clip
4. Suction with Yankaeurs-type sucker
5. Size 6 or 6.5 cuffed tracheostomy tube + spare
6. Syringe to inflate cuff
7. Connector with Ambu-bag attached
8. Oxygen supply
9. Stethoscope to check air-entry to lungs
10. Spare 12G venflon + 10-mL syringe

Surgical cricothyroidotomy is a more controlled procedure and the skin should be properly prepared with antiseptic and local anaesthetic with vasoconstrictor given to make the procedure easier. It also protects against the risk that the patient's conscious level may rise as a result of the improved oxygenation and also the pain associated with a procedure not carried out with local anaesthetic. An experienced surgeon may elect to go straight to surgical cricothyroidotomy, bypassing the needle and jet insufflation. It is important to familiarize yourself with the equipment and to check the cuff on the tube before proceeding.

If a needle cricothyroidotomy has been performed, once the area has been cleaned with antiseptic, local anaesthetic given and the necessary equipment is to hand, then conversion to surgical cricothyroidotomy should be made.

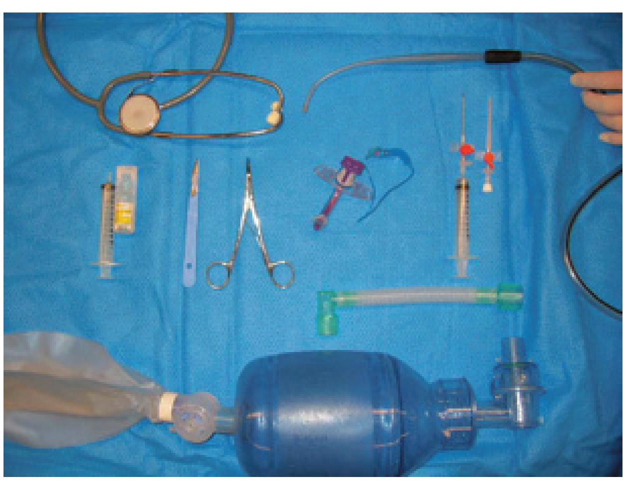


Figure 16.3 Equipment needed for surgical cricothyroidotomy.

Ideally, this should be within 5–10 minutes of the needle cricothyroidotomy.

Remove the venflon – it is in the way, making the procedure more difficult and runs the risk of cutting it with the scalpel if it is left *in situ*. Hold the skin under tension and make a 3-cm horizontal incision so that the skin edges part, revealing the membrane. Stab vertically down with the blade through the membrane and draw the blade towards you, making a hole approximately 1 cm long. Do not twist the blade in your hand or turn the scalpel round in your hand to use the handle to open up the membrane. These risk either snapping the blade (the thyroid and cricoid cartilages can become calcified) or sustaining a sharps injury.

Put the scalpel down, pick up the tracheal dilator and insert it into the cut membrane horizontally (so that it engages against the inferior surface of the thyroid cartilage and the superior surface of the cricoid) and open it so that the cut edges of the membrane are separated, exposing the trachea.

Technique

1. In-line immobilization of head by assistant
2. Universal precautions
3. Prepare the skin with antiseptic and local anaesthetic + vasoconstrictor
4. Tense the skin with finger and thumb
5. Remove the cricothyroidotomy venflon
6. 3-cm horizontal incision through the skin so that skin edges part
7. Stab vertically down through membrane and make 1-cm incision
8. Insert tracheal dilator (or curved haemostat) horizontally and open it so that it separates the thyroid and cricoid cartilages
9. Keep dilator in place. Insert Yankaeurs sucker to clear trachea
10. Insert tracheostomy tube, remove introducer, inflate cuff
11. Connect to Ambu-bag and oxygen supply
12. Assess oxygen saturation, end-tidal CO_2 and air-entry to lungs
13. Fix tracheostomy tube with tapes or sutures

Suction out the trachea with the Yankaeurs sucker and assess the trachea. Insert the tracheostomy tube into the trachea. After removing the central introducer, inflating the cuff and connect to an Ambu-bag and oxygen supply, assess air entry to both sides of the chest and start to monitor oxygen saturations and end-tidal CO_2.

If all is well, then secure the tracheostomy tube with either the tapes provided or sutures. If insertion fails then either open up the trachea again with the dilator, apply oxygen, suction and reassess or even go back to reinserting a venflon and further jet insufflation.

Potential complications

1. Failure to insert tracheostomy tube into trachea
2. Haemorrhage
3. Damage to trachea, oesophagus and neighbouring structures
4. Aspiration of blood and asphyxia
5. Damage to vocal cords
6. Creation of false passage
7. Surgical emphysema

OTHER SURGICAL AIRWAYS

1. Percutaneous tracheostomy
2. Surgical tracheostomy

As the trachea passes caudally below the cricoid cartilage, it becomes progressively posterior (deeper) and access to the trachea becomes more difficult and hazardous both because of poorer visibility and also the rich vasculature of the area and the thyroid gland.

Neither of these techniques should therefore be considered as an emergency procedure. Ideally, they are performed on an already endotracheally anaesthetized patient, as an elective operation. This may be as a prelude to major head and neck cancer surgery or before definitive treatment of severe maxillofacial trauma, enabling the airway to bypass the planned operative field. Alternatively, they may be required for a patient on long-term ventilation to enable bronchial toilet. Both techniques provide a definitive airway – a cuffed tube in the trachea.

Occasionally, an awake tracheostomy must be carried out under local anaesthetic on a patient maintaining his own airway (but in danger of losing it) where oro- or naso-tracheal intubation cannot be performed. Severe fascial-space infections, such as Ludwig's angina, with tense swelling of the tissues of the neck and around the upper airway, often with associated trismus, make either endotracheal intubation or awake tracheostomy a difficult and hazardous procedure. Frequently, an experienced anaesthetist may be able to perform an awake naso-tracheal intubation with an intubating fibre optic bronchoscope, thereby avoiding the need for the tracheostomy. However, it is wise to have the potential incision marked out and the local anaesthetic already injected in case the attempted intubation fails.

Percutaneous tracheostomy

Percutaneous tracheostomy is an elective procedure that enables a definitive airway to be placed using an essentially blind (closed) technique. It is not suitable for children as the airway is small and the trachea is mobile and soft, making the procedure technically much more difficult. It is therefore a procedure that can be carried out, on adults, in the intensive care unit, particularly for an already orotracheally intubated patient requiring a tracheostomy for longer term airway support.

This is a sterile 'surgical' procedure and the field should be properly cleaned and draped. The tracheal rings should be palpated below the cricoid cartilage and local anaesthetic with vasoconstrictor injected both subcutaneously and also more deeply down to the trachea. Assuming there is no risk of cervical spine injury, the neck can be fully extended, facilitating the procedure.

The operation is based on the Seldinger technique, whereby a guidewire is slid down through a large-bore venflon inserted into the trachea, usually between tracheal rings two and three. As soon as the guidewire is in the trachea, its position can be checked by viewing down the orotracheal tube with an intubating bronchoscope. The guidewire is left *in situ* while the venflon is removed and then progressively larger dilators are introduced over the guidewire. When the tract is adequately dilated, the tracheostomy tube can be slid into place. Usually it is sensible to let the orotracheal cuff down (to reduce the risk of puncture by the venflon or guidewire) at the beginning of the procedure and to withdraw the tube slightly to facilitate insertion of the dilators and tracheostomy tube. The orotracheal tube must still remain through the vocal cords until satisfactory position and function of the tracheostomy tube is confirmed. Percutaneous tracheostomy is a time-consuming procedure that should be carried out when the airway is already protected with a definitive tube in place.

Surgical tracheostomy

Surgical tracheostomy is an elective 'open' technique which again is ideally performed on an already intubated patient. Before fibre optic intubation and the wider acceptance of surgical cricothyroidotomy, emergency tracheostomy was more frequently attempted. Under such circumstances, it is an extremely hazardous procedure and was associated with significant mortality due to distorted anatomy, poor access and visibility and associated haemorrhage.

Indications

1. Elective procedure for airway to bypass planned operative field
2. Long-term respiratory support
3. Protection of airway from obstruction by tumour
4. Congenital anomalies, e.g. subglottic stenosis
5. Retention of secretions

If the patient is anaesthetized and assuming there is no risk of cervical spine injury, the neck should be fully

extended. If tracheostomy under local anaesthetic is being performed, the patient may not tolerate well lying back and a compromise position may be needed with the patient partially sitting up.

Whether under general or local anaesthetic, local anaesthetic should be liberally injected throughout the whole operative field, both into the skin and also down through the deeper tissues to the trachea. A 5-cm transverse incision should be made halfway between the cricoid cartilage and the suprasternal notch (Figure 16.4). Subcutaneous fat and platysma are divided and retracted and fastidious haemostasis must be maintained throughout the procedure. Blunt scissor-dissection absolutely in the midline will show the strap muscles on either side which should be retracted. Keep palpating the tracheal rings through the incision to ensure that dissection continues in the midline.

The thyroid isthmus will be seen. Although it may be possible to retract this, it is safer to divide it (Figure 16.5). The pretracheal fascia should be divided at the superior end and the thyroid isthmus gradually lifted off the trachea from above downwards before clamping, dividing and tying the ends off and retracting them to the sides (Figure 16.6). There is still some pretracheal fascia that must be carefully dissected to come down on to the tracheal rings. Identify the second and third rings.

The anaesthetist should be warned that the trachea is about to be incised, so that the endotracheal tube cuff can be let down and the tube retracted a couple of centimetres to avoid risk of cutting into the cuff. The tube must remain between the vocal cords until safe and satisfactory placement of the tracheostomy tube has been confirmed by checking the end-tidal CO_2 and O_2 saturation.

Using a No. 11 scalpel incise transversely through the membrane between the second and third tracheal rings. Cut down through the third ring and excise a window about 1 cm in diameter (Figure 16.7). In children, a vertical incision in the midline through the third and fourth tracheal rings should be made. Stay sutures should be inserted on either side of the incision and retracted, opening up the incision into the trachea (Figure 16.8). Having sized (the same as the orotracheal tube *in situ*) and checked the tracheostomy tube cuff, insert it into the trachea, inflate the cuff, connect up to the anaesthetic tubing and assess the end-tidal CO_2. If all is satisfactory, then the skin incision can be closed around the tracheotomy tube and the tube secured either with the tapes provided or by suturing the flanges with heavy duty sutures. Once airway entry has been identified in both lung fields, the orotracheal tube can now be removed.

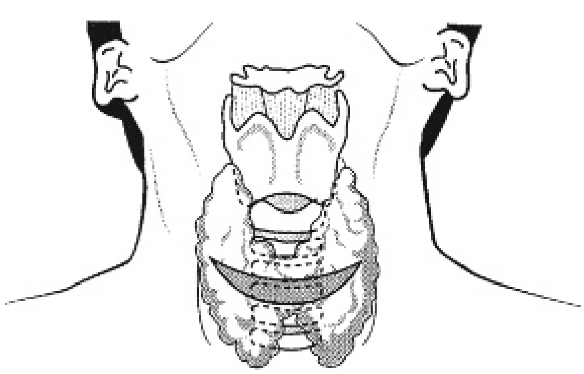


Figure 16.4 Skin incision for elective tracheostomy.

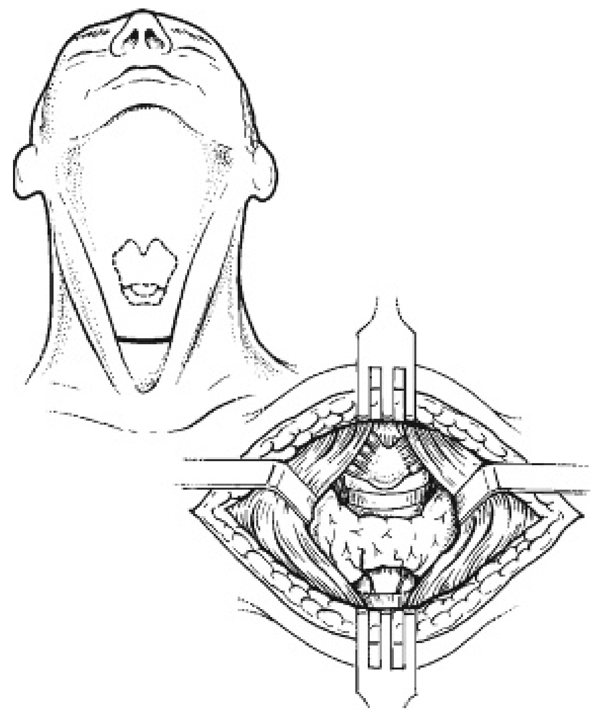


Figure 16.5 Tracheostomy dissection showing the thyroid isthmus overlying the trachea.

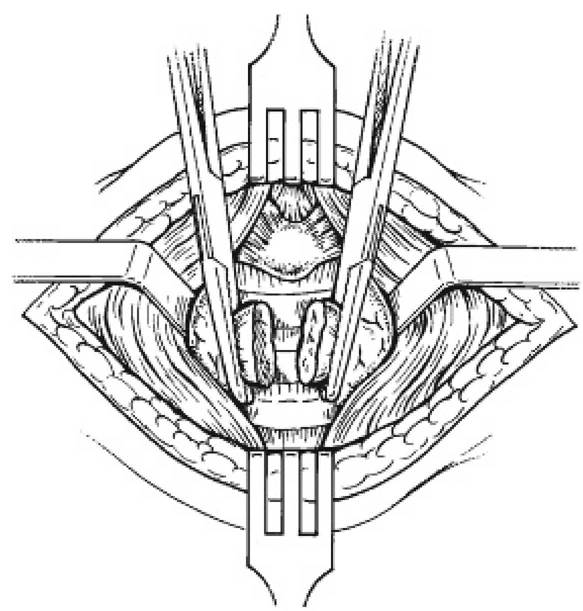


Figure 16.6 The thyroid isthmus is clamped and divided.

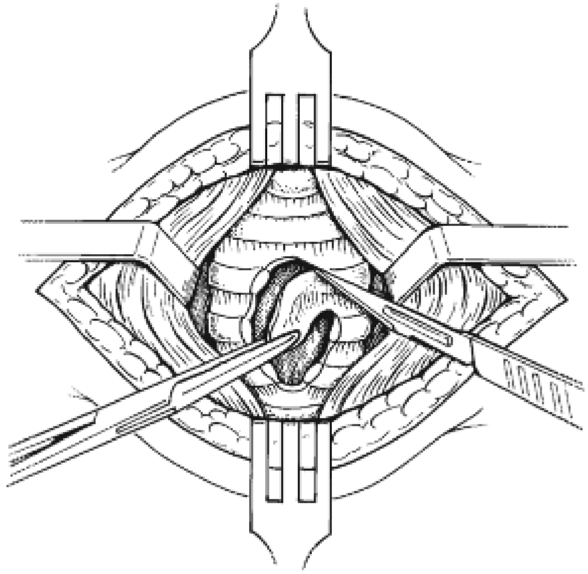


Figure 16.7 A circular window is created using a scalpel with a No. 11 blade.

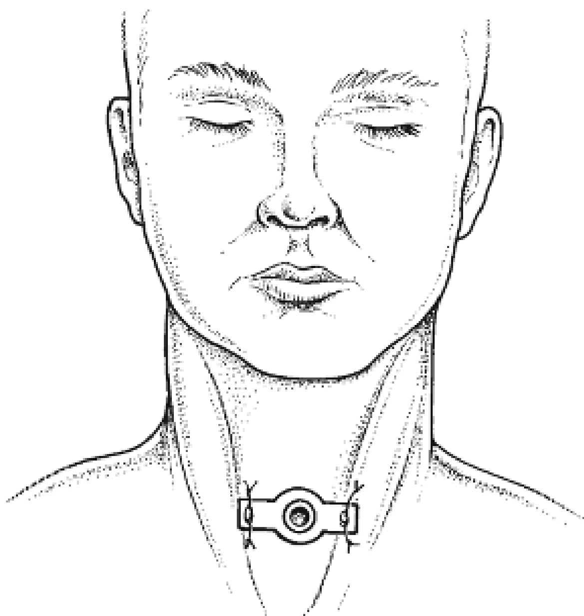


Figure 16.8 The tracheostomy tube flanges are sutured to the skin.

It is important to ensure adequate humidification of the air or oxygen to prevent crusting within the lumen and potential obstruction. If the tracheostomy is being performed for longer term use, then a double lumen tube can be inserted. This enables the inner tube to be removed and cleaned without affecting the position of the tube itself.

Technique

1. Neck fully extended, patient anaesthetized and intubated.
2. Universal precautions and site prepared and draped.
3. Local anaesthetic with vasoconstrictor both to skin and deeper tissues.
4. 5-cm slightly curved (smiling) incision in skin crease, halfway between cricoid cartilage and suprasternal notch.
5. Careful haemostasis with bipolar diathermy throughout.
6. Dissection down through fat and platysma in midline, exposing the strap muscles of the neck.
7. Blunt scissor-dissection in midline separating strap muscles and retracting them laterally.
8. Thyroid isthmus should be identified, clamped, divided and tied off.
9. Continue careful dissection down to tracheal rings – identify second to third tracheal rings.
10. Inform anaesthetist to let down cuff and slightly withdraw tube.
11. Check tracheostomy tube size (same as orotracheal tube being used) and cuff.
12. Cut with No. 11 scalpel blade horizontally through membrane between rings two and three; continue this to excise a window, including the anterior surface of the third tracheal ring.
13. Suck out trachea, insert tracheostomy tube.
14. Inflate cuff, connect to anaesthetic tube, check end-tidal $p\mathrm{CO}_2$ and oxygen saturations.
15. Close skin incision around tube with 3-0 sutures.
16. Secure tracheotomy tube with tapes or 1-0 sutures.

UNCONTROLLED MAXILLOFACIAL HAEMORRHAGE

It is important to be familiar with measures which can be employed to arrest maxillofacial haemorrhage.

Intra-oral haemorrhage following exodontia usually can be addressed with the use of local anaesthesia with vasoconstrictor, packing and suture. Elsewhere in the maxillofacial region, haemorrhage needs to be dealt with promptly and effectively as large volume blood loss can occur quickly if not adequately controlled. As always, airway and breathing must be addressed first and a secure definitive airway placed and supplemental oxygen supplied before addressing the circulation. While the patient continues to haemorrhage, fluid resuscitation alone will be unsuccessful; blood loss must also be controlled.

Haemorrhage may be arrested by direct pressure on a wound when a bony structure lies deep into the laceration, as in the scalp. In the face, lip, peri-orbital area and neck, such compression seldom controls blood loss and in these circumstances, clamping and ligation of transacted vessels will be required. Where the soft tissues are extensively disrupted as in high energy injuries such as gunshot wounds,

haemorrhage control may only be achievable with ligation of the external carotid.

Where severe midfacial bony trauma has occurred (with Le Fort II or III fractures) and torrential nasal haemorrhage has resulted, and where anterior and posterior nasal packs have been unsuccessful, forward manipulation of the maxillary segment may stop maxillary artery haemorrhage. If this fails, external carotid artery ligation is indicated.

Insertion of Foley catheter to nasal cavity

Severe nasal haemorrhage

This commonly follows maxillofacial trauma, but may also occur in uncontrolled hypertension or indeed spontaneously. When there is no history of trauma, sitting the patient up and applying pressure to the area may result in sufficient control to be able to examine the nose and, if necessary, cauterize the bleeding point using local anaesthetic, bipolar diathermy or silver nitrate sticks.

An anterior nasal packing with ribbon gauze soaked in a fluid such as SofradexR should control anterior bleeds. Use of expansile cellulose devices such as MerocelR is a simple method of haemorrhage control.

Post-nasal packing will be required if bleeding is from the post-nasal space or if severe trauma has resulted in severe bleeding requiring both anterior and post-nasal packing. Either Epistat (a preformed device with inflatable balloons for both posterior and anterior packing) can be used or, alternatively, Foley catheters are introduced into both nasal cavities and advanced along the nasal floor until they reach the soft palate (Figure 16.9). The balloons are inflated with sterile saline and then gentle traction is applied to both catheters until the balloons lodge at the posterior nasal choanae. The catheters can be held in position by tying them together around the anterior nasal spine. The catheters are deflated at 24 hours and, if no epistaxis ensues, can be removed.

In patients with Le Fort II or Le Fort III fractures and disruption of the cribriform plate, care must be taken to ensure that the Foley catheters and packing are not aimed cranially, with risk of forcing them into the cranial cavity.

Nasal packing is only effective by tamponading the bleeding vessels against a solid base provided by the rigid floor of the nose. Occasionally, with severe midface trauma and Le Fort I level fracture, such packing just acts to displace the maxillary fracture rather than compressing the bleeding vessels. Placing bilateral mouth props to support the maxilla against an intact mandible may help. In the additional presence of displaced or comminuted mandibular fractures, cranial (barrel) bandaging may help until such time as definitive intervention can be provided.

Rarely, severe nasal haemorrhage is not controlled by these approaches. Ethmoidal artery ligation can be considered and is usually achieved endoscopically. Where these skills are not available, the anterior ethmoid artery can be ligated via a medial orbital approach (Figure 16.10).

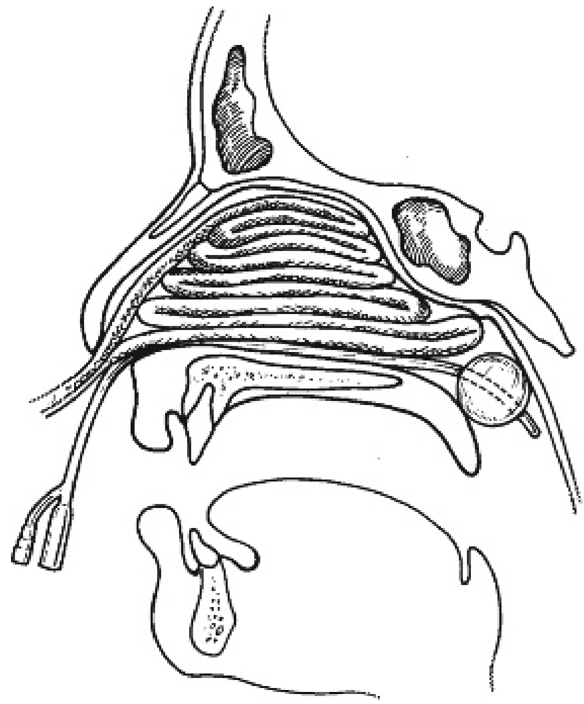


Figure 16.9 Nasal packing showing Foley catheter in post-nasal space and anterior nasal packing with ribbon gauze.

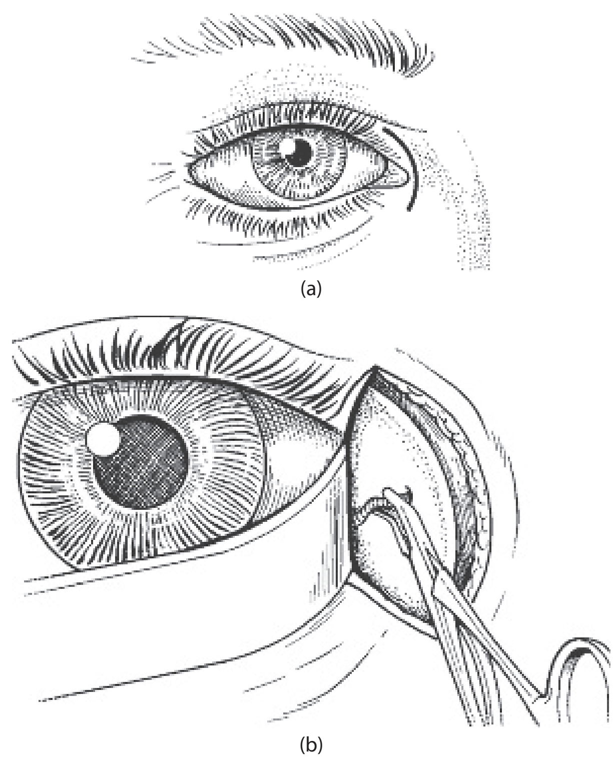


Figure 16.10 (a) Inner canthal incision; (b) the anterior ethmoidal artery is clamped with a ligaclip.

Post-nasal packing

1. Push Foley catheter with 20-mL balloon along floor of nose until it is visible behind the soft palate; repeat for the second side.
2. Inflate the balloons.
3. Pull the catheters forward until the inflated balloons occlude the post-nasal choanae.

Anterior nasal packing

Pack the nasal floor and cavity with 5-cm ribbon gauze, soaked with Sofradex® or bismuth iodoform paraform paste (BIPP).

Technique for ligation of the anterior ethmoidal artery

1. General anaesthesia.
2. Also give local anaesthetic and vasoconstrictor.
3. 2.5-cm curved incision at inner canthus – see Figure 16.10.
4. Deepen down to bone.
5. Elevate periosteum, aiming posteriorly subperiosteally.
6. Anterior ethmoidal artery is identified at its foramen, 2.5 cm from the orbital rim and just above the medial canthal ligament.
7. Ligate either with ligaclips or bipolar diathermy.

EXTERNAL CAROTID ARTERY LIGATION

This procedure is indicated where torrential haemorrhage in the area supplied by that artery has not been controlled by other means. This may arise as a result of maxillofacial trauma but is very occasionally warranted during ablative oncological surgery of the tongue or maxilla. In general terms, if significant haemorrhage is anticipated during an oncological procedure, a neck dissection, if appropriate, with vessel exposure should be performed prior to the ablation. Very rarely, it is required during orthognathic procedures.

The patient is prepared, anaesthetized and positioned with the neck extended and rotated to the contralateral side. Where the neck has already been accessed for another procedure, such as a neck dissection, this approach is used. In non-oncology cases, rapid access is best achieved with a 5-cm incision along the anterior border of sternomastoid. Dissection through the subcutaneous fat and platysma exposes the muscle. The deep cervical fascia investing sternomastoid is divided, the muscle retracted posteriorly and the internal jugular vein is exposed. The jugular vein is mobilized by dissecting the carotid sheath and freeing the vein superiorly and inferiorly. The common carotid artery will be seen medially (see Figure 16.11). At this point the anaesthetist should be warned as manipulation of the carotid bulb at the bifurcation may cause cardiac dysrhythmias.

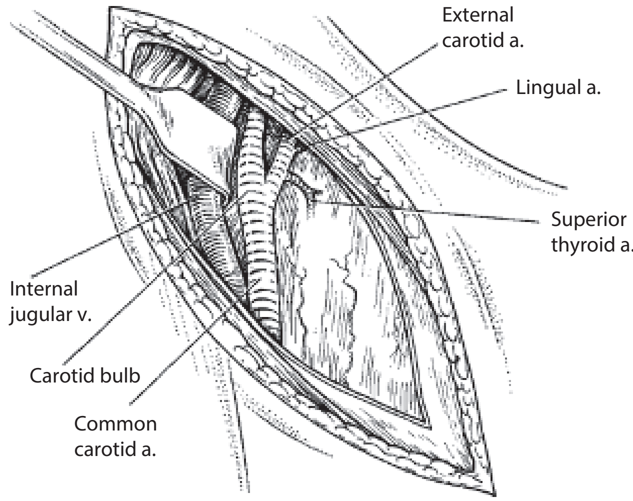


Figure 16.11 The carotid sheath is opened to expose the internal jugular vein and carotid artery.

The artery is followed superiorly to the bifurcation and the (anterior, multiple branching) external carotid is identified. The hypoglossal nerve is an adjacent structure and should not be damaged. Prior to ligation of the vessel, the external carotid should be clamped with a non-crushing vascular clamp to confirm that haemorrhage can be controlled by this procedure. Very occasionally, especially in midface trauma, exposure of the contralateral external carotid may be required to achieve haemorrhage control. In very difficult situations, the assistance of an interventional radiologist may be required to identify the disrupted vessel or consider translumenal methods of haemorrhage control.

Technique

1. General anaesthesia, patient's head-up, neck extended and rotated contralaterally.
2. 5-cm incision along anterior border of sternomastoid.
3. Dissect down through fat, platysma and deep cervical fascia.
4. Retract sternomastoid posteriorly.
5. Open up carotid sheath exposing internal jugular vein.
6. Free up vein inferiorly and superiorly, exposing common carotid artery deep to the vein.
7. Follow artery superiorly to bifurcation.
8. Clamp external (more anterior + with branches) carotid.

ACUTE RETROBULBAR HAEMORRHAGE

This condition is one of the few true emergencies in maxillofacial surgery. The presence of orbital pain, reducing visual acuity, proptosis and ophthalmoplegia in the acute presentation of midface trauma or following surgical management should be assumed to be a retrobulbar

haemorrhage. Fundoscopy to note a pale optic disc is the only investigation required – computed tomography (CT) imaging wastes time and rarely assists the diagnosis.

Symptoms and signs

Acuity – reducing
Pain – increasing
Proptosis
Paralysis of ocular muscles – ophthalmoplegia
Pupils – dilating
Pale optic disc

Management

On diagnosis, several simple preliminary steps are of value in preserving or restoring vision.

1. Basic steps are as follows:
   a. Sit the patient up if their condition permits.
   b. Remove all dressings around the eye.
   c. Remove the skin and deep sutures immediately if peri-orbital lacerations (or surgical incisions) have been sutured. This may allow decompression of the orbit.
   d. Site two venous cannulae.
2. Medical management, which include the following:
   a. 1 g of methylprednisolone intravenous (iv) stat.
   b. 200 mL of 20% mannitol infused over 15–20 minutes.
   c. Acetazolamide 500-mg iv if available.
3. Perform a lateral canthotomy as follows:
   a. 2 mL of 2% lignocaine and adrenaline are injected into the lateral canthal region. Sharp dissecting scissors are used to divide the lateral canthus through the lateral fornix down to periosteum – this will release some pressure and will buy time before formal intra-conal decompression.

Following this intervention, book theatres and an anaesthetist, explaining the urgency of sight preserving surgery. Surgical decompression is almost always required and should never be delayed. However, some clinicians advocate megadose steroid therapy alone, with surgical intervention only if no clinical improvement is seen within 30 minutes. The surgical aim is to decompress the intra-conal space and a surgeon who performs this procedure for the first time should not expect to encounter a copious bleed.

Surgical decompression

The approaches possible are as follows:

1. Through an existing laceration or surgical incision
2. Via a lateral eyebrow incision (Figure 16.12)
3. Via an infra-orbital approach

It is important to avoid an incision in eyelid skin, such as a blepharoplasty approach, since this technique also confers a risk of a retrobulbar bleed.

The peri-orbita is incised and the intra-conal space entered by blunt dissection between the lateral and inferior rectus muscles (Figure 16.13). Any surgical implants should be removed.

A small drain (or the finger of a surgical glove) is sutured in place and left for at least 24 hours.

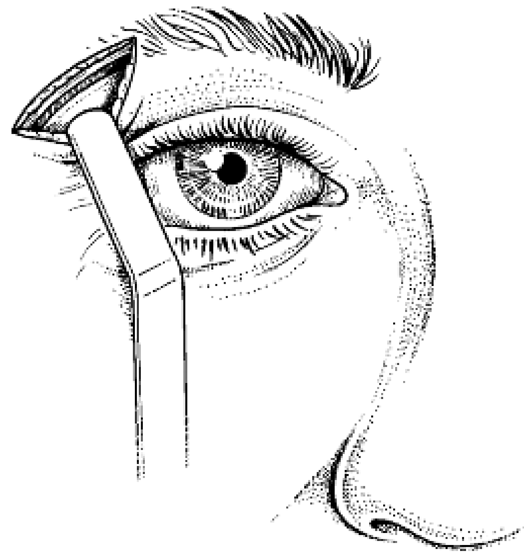


Figure 16.12 A lateral brow incision is performed and the peri-orbita incised.

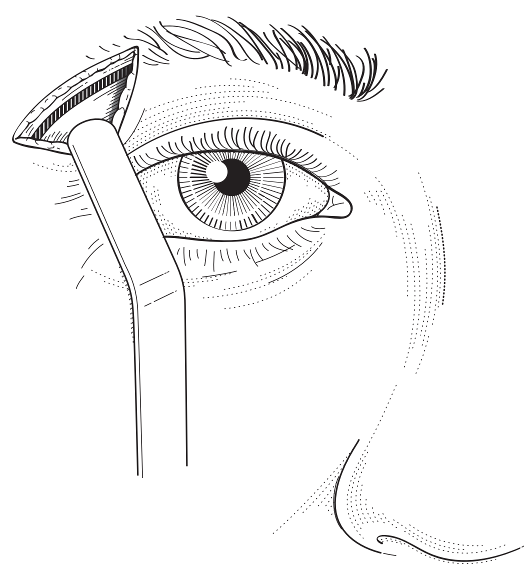


Figure 16.13 The intra-conal space is opened by blunt dissection.

No attempt should be made to treat any bony injuries at this stage. A retrobulbar haemorrhage is commonly associated with comminution of the orbital floor and therefore required detailed CT evaluation. Additionally, there is an increased risk of a further bleed when definitive treatment is undertaken. Surgical treatment would therefore be contraindicated where the contralateral eye is visually impaired because of pre-existing pathology.

Following medical and surgical management, close eye observations are mandatory. Any increasing pain or visual deterioration may indicate re-exploration. Further doses (250 mg) of methylprednisolone are warranted at 8-hourly intervals for 24 hours, but the blood glucose should be monitored, especially in diabetics.

Top tips

- Airway and haemorrhage are two of the most significant emergencies to be dealt with in maxillofacial surgery.
- Surgical tracheostomy is always an elective procedure once initial airway control has been achieved.
- The technique of needle cricothyroidotomy is a life-saving procedure with which all trainees need to be conversant.
- Arrest of haemorrhage is critical – iv resuscitation alone cannot be effective with an open circulation.
- Retrobulbar haemorrhage is a medical and surgical emergency. Always consider this diagnosis as it can be missed or recognized too late to save vision.

17

Reconstructive surgery – Local and pedicled orofacial flaps

NABIL SAMMAN

CONTENTS

This chapter covers the principles and practical usage of selected local and pedicled flaps in the oral and facial regions to repair or restore relevant congenital and acquired tissue defects and deformities.

Although the list of selected procedures is not comprehensive, those covered in this chapter arguably represent some of the most common and most useful in the broad armamentarium of the surgeon dealing with orofacial defects and deformities.

Each procedure is described and illustrated in a way to highlight the key features relevant to its use, the 'pearls and pitfalls' specific to that procedure. No attempt is made to cover any of the aspects important to the management of the pathologic condition that may have given a reason for performing the procedure as that would be impractical in a chapter devoted to operative aspects.

MUCOSAL ADVANCEMENT AND ROTATION FLAPS

Buccal advancement flap

Principles – The classical example of the buccal advancement flap is in the closure of an oro-antral fistula (OAF) resulting from an upper molar extraction. This is a random flap that depends on the principle of a wider base to ensure adequate blood supply for the advancing mucoperiosteal tissue. The ratio of width of the base to length of the flap must not be less than 1–2. A similar flap is used to close over an alveolar cleft after bone grafting with the advancement being in the anterior direction. Periosteal release incision is an essential component of the procedure to enable the desired advancement without tension and adds safety to the sutured flap during function.

Pitfalls – Flap dimension depends on the size of the fistula and must ensure a wider base.

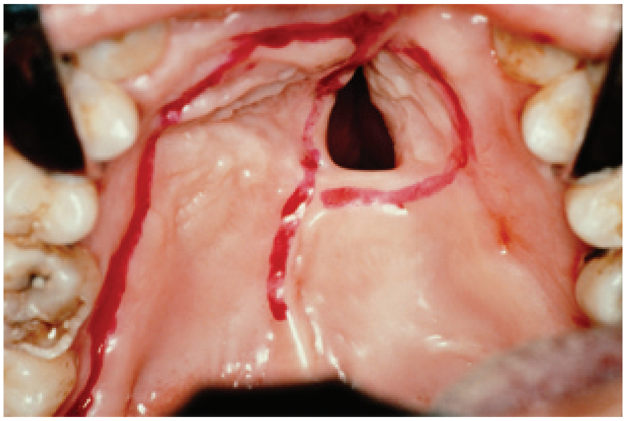
Inadequate periosteal release leading to tension on the suture line and dehiscence.

Palatal rotation flap

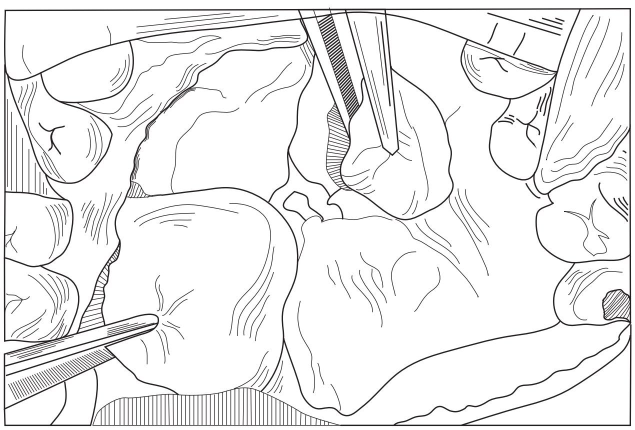
Principles – This is an axial flap based on the greater palatine artery and thus can be raised all the way forward to the incisor region; but care must be taken to ensure a subperiosteal dissection off the palatal bony shelves which can be difficult in adults and progressively so with increasing age due to the irregular surface of the palatal bony shelves.

The arc of rotation of the palatal rotation flap (PRF) is centred on the axial vessel and can reach close to 90° on each side thus enabling rotation to close an OAF laterally or a palatal oronasal fistula medially. However, no forward movement is possible.

Procedure – The flap is outlined starting 0.5–1 cm from the attached gingiva buccally up to the midline medially, with the length varying according to the need. Once the flap is raised it is rotated and sutured over the defect (which should already have a nasal layer closure completed), as an oral layer. The exposed bone of the palate is covered with Whitehead's varnish or bismuth iodoform gauze for 10 days (Figure 17.1).



(a)



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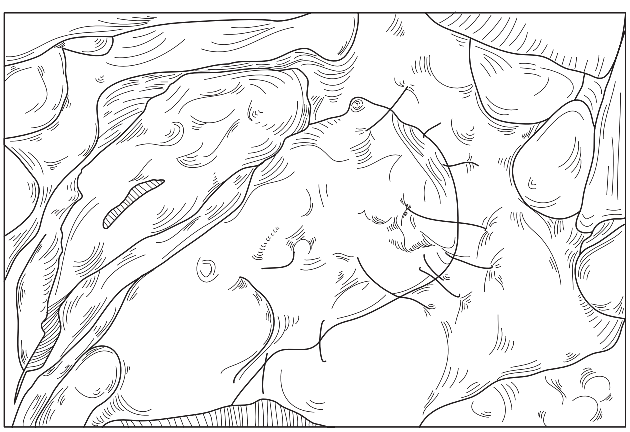


(c)

Figure 17.1 (a) Palatal fistula with outline of palatal axial rotation flap and turnover lining flap. (b) Turnover flap closes the fistula as inner lining. (c) Axial flap rotated to provide cover over the lining turnover flap.

Pitfalls – Inadvertent raising of the mucosa without the artery, the latter remaining tethered in the irregular bony surface of the palatal shelf.

Trauma to the pedicle during flap raising.

Haemorrhage from vessels at the edge of the flap.

BUCCAL FAT PAD

Principles – The buccal fat pad (BFP) as a pedicled flap has a random blood supply from the maxillary, superficial and facial arteries. It is a mass of fatty tissue located between the buccinator muscle and mandibular ramus extending below the zygomatic arch into the temporal fossa and surrounded by a thin fascia. The BFP is capable of lining an oral defect and epithelializing within 3–4 weeks. Use of the BFP is suitable for closure of an ipsilateral check defect, a maxillary bone defect or an OAF.

Procedure – Access to the BFP is easy as it has a tendency to herniate into the oral cavity once its fascial envelope is breached. The most convenient site for access to the BFP is at the level of the coronoid process in the buccal vestibule through a periosteal incision, however, it is mostly accessed through the excision or resection defect.

Mobilization of the BFP is achieved indirectly by opening the fascial envelope with blunt dissection movement of the scissors thus prompting further herniation of the BFP into the surgical defect by gravity.

Suturing the BFP without tension using a round body needle taking two bites of the BFP for each mucosal suture. No dressing or graft required. Mucosalization begins immediately (Figure 17.2).

Pitfalls – Handling of the BFP must be gentle to avoid traumatic fat necrosis or disintegration of the tissue mass and avascular fat necrosis.

Avoid masticatory trauma by use of nasogastric feeding in cases of maxillary bone defect repair.

TONGUE FLAP

Principles – The tongue flap is a pedicled random flap based on the submucosal vascular plexus. It is typically raised at about 7–10 mm thickness to ensure full inclusion of the vascular plexus and a narrow cuff of tongue muscle. The principle of 2:1 length to base width ratio thus applies and the flap may be anteriorly or posteriorly based. It is most commonly used to repair an oronasal fistula in the hard palate but may also be used to provide mucosal lining for a partial-thickness upper or lower lip defect.

Procedure –Local anaesthesia may be used and diathermy is best not used on the flap itself. The flap is raised by the knife taking care to raise it at the level of tongue muscle throughout. Planning the flap length must take into account the location of the defect to enable reaching the whole defect and suturing without tension. Six equidistant sutures in total on the flap are generally sufficient.

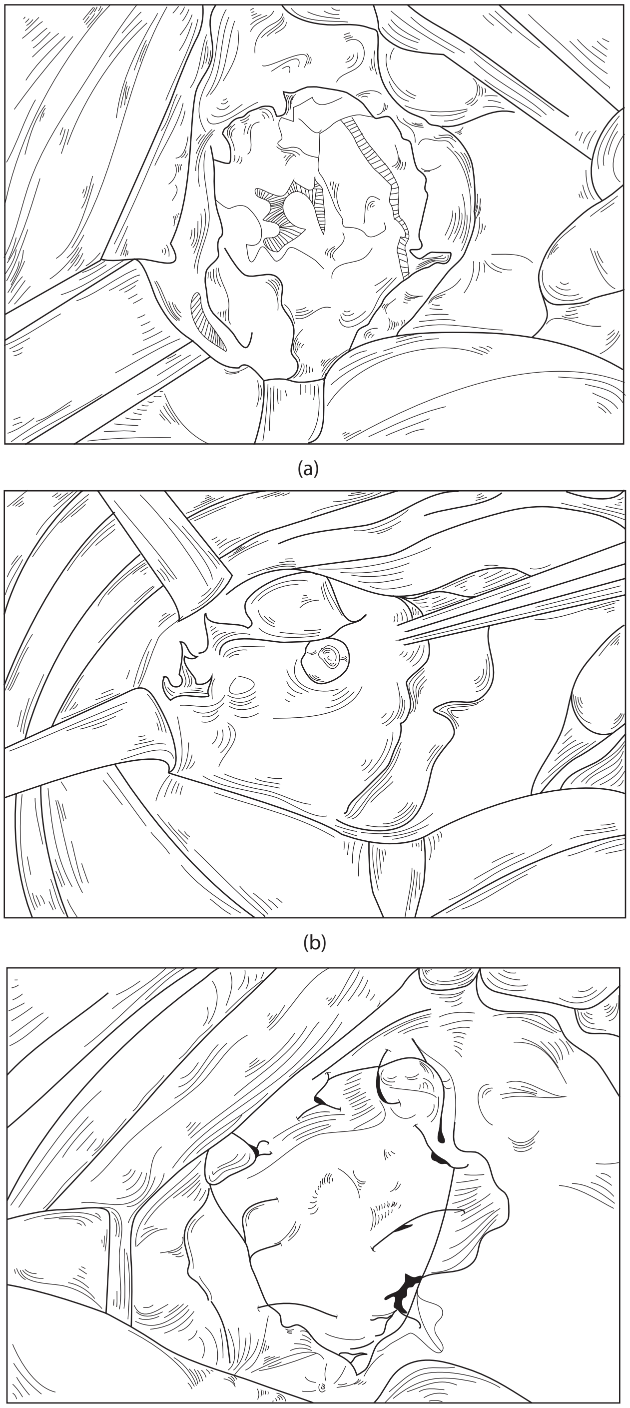


Figure 17.2 (a) Maxillary defect with BFP visible. (b) BFP mobilized to reach defect perimeter. (c) BFP sutured to defect margins providing a single layer cover.

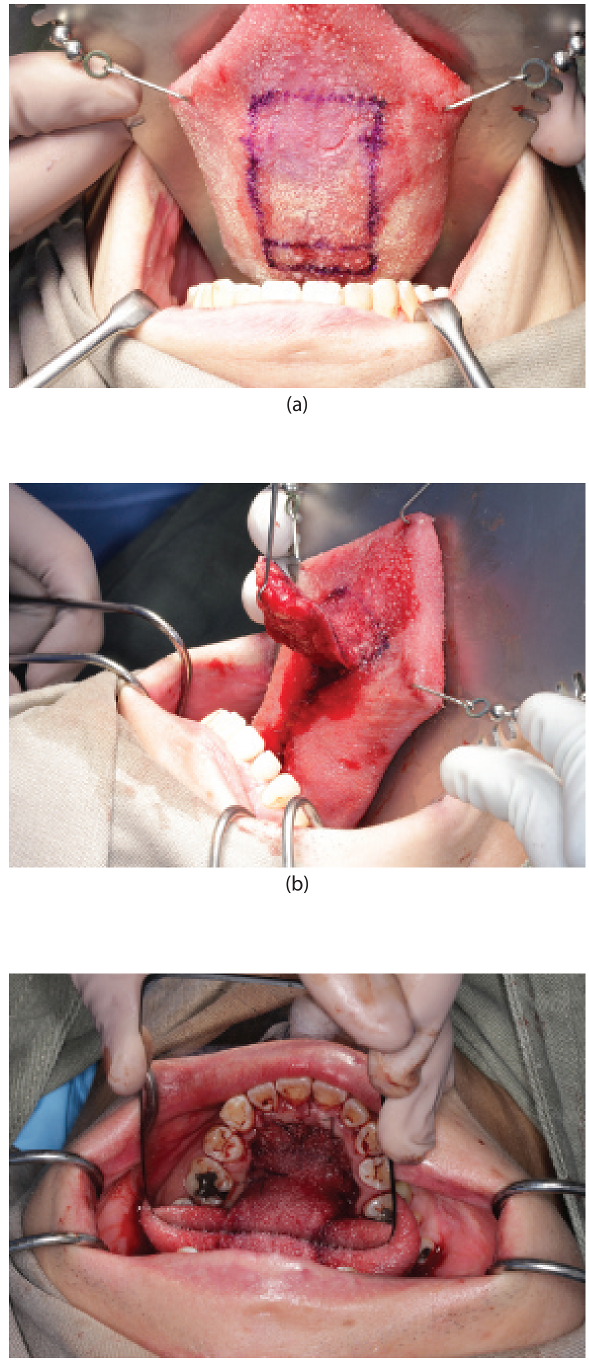


Figure 17.3 (a) anteriorly based tongue flap outline. (b) Flap raised and donor site closed primarily. (c) Mirror view of tongue flap inset to palatal defect.

Division of the pedicle is done 2 weeks post-operatively (Figure 17.3).

Pitfalls – Short flap, thin flap, loose sutures, uncooperative patient (consider inter-maxillary fixation).

– Two-layer closure for oronasal fistula is preferred (nasal layer created by everting palatal tissue around fistula thus increasing diameter of oral defect and flap width requirement).

ABBE FLAP

Principles – The Abbe flap is an axial flap based on the lower labial branch of the facial artery. It is generally used as a midline flap to correct a defect of the upper lip, often in bilateral cleft patients or after excision of pathology. It is a lip-switch flap whereby one labial artery is divided and the full-thickness (FT) lower lip is turned upward, pedicled on the contralateral vessel and sutured to the upper

lip. The donor site is closed primarily and the pedicle is divided 2 weeks after operation.

Procedure – Measurement and marking of the required length and width are done before local anaesthesia with vasoconstrictor is given.

The lower lip is cut through and through on one side and the position of the labial artery in relation to the vermilion is noted to facilitate avoidance of damage to the contralateral vessel and enable dissection close to it. With the pedicled flap raised and supported by a skin hook, the donor site is closed. The flap is inset in the upper lip and sutured in three layers (mucosa, muscle and skin) taking care to restore form and continuity of upper lip while not endangering the pedicle (Figure 17.4).

Pitfalls – Damage to the pedicle by excessive dissection close to it can be avoided and adjustment in final flap insetting is done at pedicle division stage.

TEMPORALIS MYOFASCIAL FLAP

Principles – The temporalis myofascial flap (TMF) is an axial flap based on the anterior and posterior branches of the deep temporal arteries for its muscle component, while the deep temporal fascia overlying the muscle is supplied by the superficial temporal artery (which is necessarily divided whenever the TMF is raised).

The TMF is a reliable bulky muscle flap which can be used as a single layer to close a large maxillary defect or to fill the orbit after exenteration. It can also repair defects in the oropharynx or cheek, obliterate mastoid cavities or be used in facial palsy camouflage.

Procedure – The flap is exposed at the level of the deep temporal fascia through a hockey-stick skin incision and raising the superficial temporal fascia subperiosteally at the zygomatic arch to avoid injury to the zygomatic branch of the facial nerve.

The muscle is outlined together with the adherent deep temporal fascia and raised off the temporal bone as a whole pedicled muscle with its overlying fascia (myofascial flap) (Figure 17.5a).

Once raised, the muscle flap may be divided coronally to enable the anterior portion to be used as a pedicled flap which is then rotated under the zygomatic arch into a maxillary defect (after maxillectomy) while the posterior portion is advanced anteriorly into the temporal recess lateral to the orbital wall thus avoiding an aesthetic deformity (Figure 17.5b).

If the whole muscle is needed, then it is similarly rotated and transposed to the defect below the intact zygomatic arch (Figure 17.5c). If difficulty in transfer is encountered, the arch is temporally fractured and replated after flap transposition is complete. The donor site is camouflaged with cold-cure acrylic commercially available for the purpose.

Transfer of the flap to the defect is achieved by a combination of downward blunt pushing and upwardly inserted Kocher forceps through the defect to take delivery of the flap (Figure 17.5d).

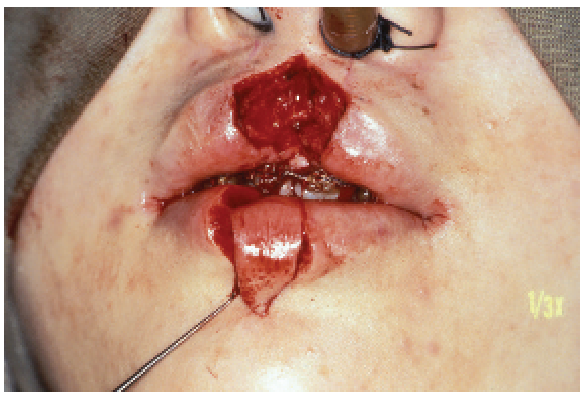
The flap is rotated in such a way that the fascial surface is left exposed in oral cavity without the need for a skin graft (Figure 17.5e). Epithelialization of the fascial surface begins immediately and is complete in 5–6 weeks.

Pitfalls – The pedicle is located on the medial aspect of the coronoid process thus flap dissection from above must avoid instrumentation near the coronoid process.

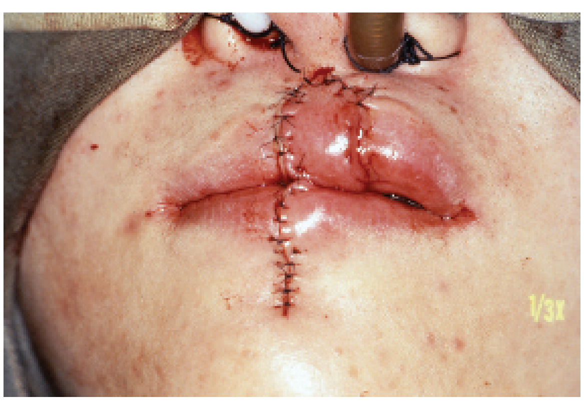
Incision to outline the extent of muscle to be raised must be made at the muscle periphery to avoid cutting into the terminal vessels located in the muscle close to its periphery. This will serve to diminish bleeding and oedema.

Delay in raising the flap will result in oedema which will make transposition below the zygomatic arch more difficult or impossible thus requiring arch osteotomy.

Transposition must be done by careful handling of the flap through the use of artery forceps at multiple sites of the muscle periphery.



(a)



(b)

Figure 17.4 (a) Abbe flap outlined ready to be rotated to upper lip defect pedicled on one labial artery. (b) Flap inset in upper lip defect as pedicled flap.

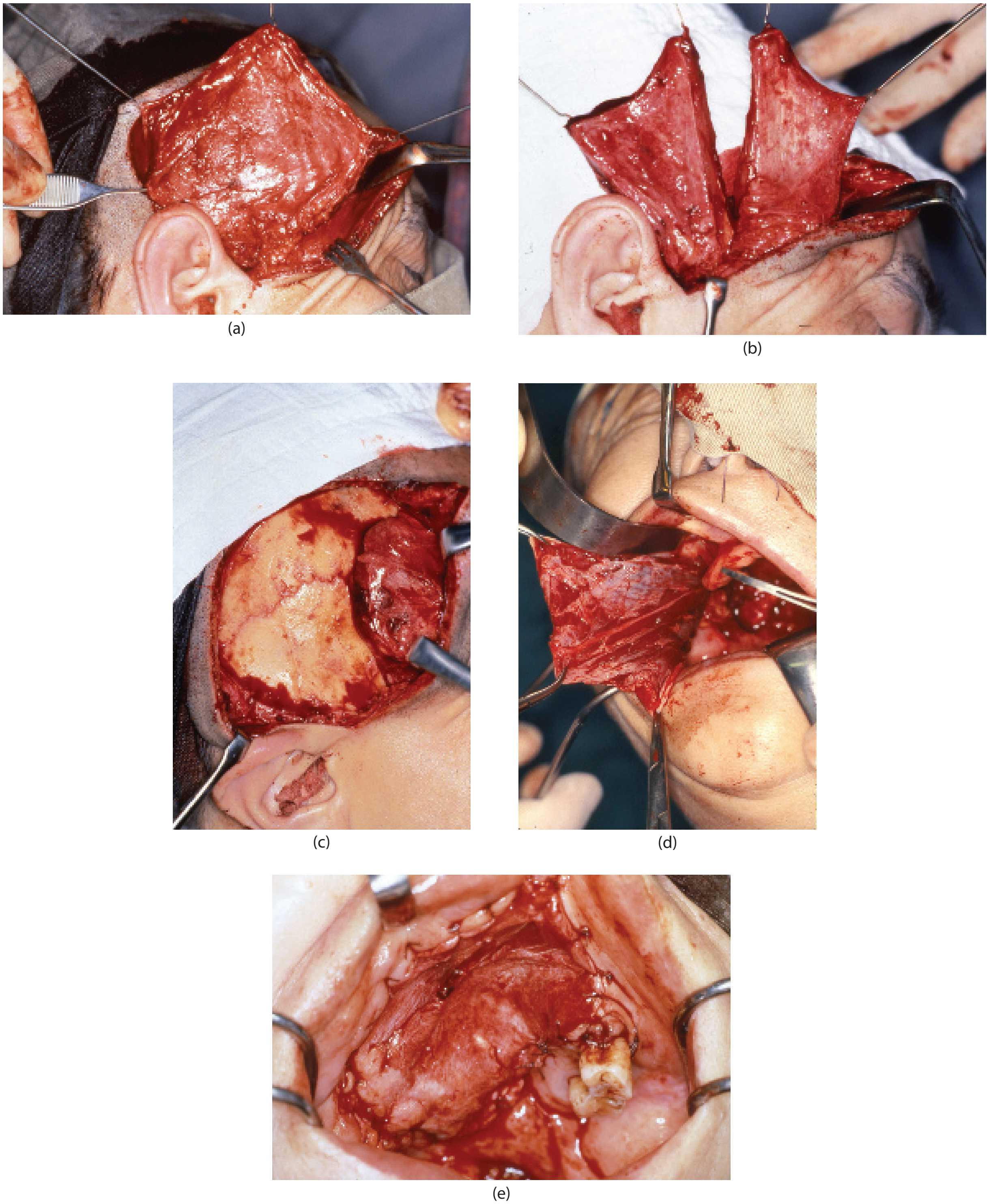


Figure 17.5 (a) Full temporalis myofascial flap raised. (b) Flap can be divided coronally into anterior and posterior segments. (c) Flap rotated below zygomatic arch down into oral cavity. (d) Flap delivered into oral cavity within reach of defect. (e) Defect closed with pedicled temporalis flap.

GALEA APONEUROTICA FLAP

Principles – The Galea flap is an axial flap that may be laterally based on the superficial temporal artery for use on the face, or anteriorly based on the supraorbital and supratrochlear arteries for use on the anterior skull base as a galea-pericranial flap. The tissue of the flap lies between the skin (just below the hair follicles) and the pericranium and is easily separated from the latter but not from the former.

The galea aponeurotica flap (GAF) in the orofacial region may be used as a subcutaneous filler to correct facial contour or as a lining of the oral cavity after cheek resection.

Procedure – The lateral flap is raised through a hemicoronal skin incision down only to the base of hair follicles. This is followed by sharp (knife) dissection just below the hair follicles in all directions to widen the exposed galeal surface as much as required taking care to preserve the superficial temporal artery. Supero-medial dissection can safely reach the midline. The flap is then raised off the pericranium easily and rotated on its pedicle as required (Figure 17.6). Transfer is done through a subcutaneous tunnel to reach the desired destination. Donor site is primarily closed.

Pitfalls – Damage to hair follicles leads to localized alopecia.

Rotation must be over (above) the zygomatic arch and the flap must not include any deep temporal fascia.

MASSETER FLAP

Principles – The muscle is fused anteriorly at the anterior ramus border while posteriorly it is split into three parts enabling the masseteric artery (between the outermost two portions) and masseteric nerve (between the middle and deepest portion) to enter the muscle from above and behind. The flap may be used when a part of the anterior ramus is resected as a crossover flap for oral/oropharyngeal lining. The other use is as an entire muscle raised for transposition to the oral commissure and upper and lower lip in cases of facial nerve palsy.

Procedure – The crossover flap is transposed across the resected ramus portion by stripping the muscle from its lowermost attachment at the angle of the mandible and raising it enough to reach the medial defects.

In paralysis cases, access to the masseter for transposition to the corner of the mouth can be achieved intra-orally or extra-orally. The whole muscle must be raised off the bone and mobilized. The lowermost portion of the raised muscle is divided longitudinally and its anterior portion sutured to the orbicularis oris anterior to the melolabial fold, while the muscle's posterior portion is sutured to the lower lip and commissure (Figure 17.7). Distal suturing of the flap at the corner of the mouth must be done through a skin incision at the melolabial fold and tied over a bolus to maintain the muscle in position over the lip and orbicularis oris for several days.

Pitfalls – Bleeding and haematoma, especially with the intra-oral approach.

Large steri-strips and bandages, nasogastric feeding to immobilize the face and maintain the mouth at rest.

SKIN GRAFTING

Principles – Free skin grafting requires a healthy recipient bed to enable graft vascularization, hence local infection, diabetes and irradiation are unfavourable factors. Close adaptation of the graft to the recipient bed is essential, hence graft dressing is critical.

FT grafts are more aesthetic but amenable to smaller dimensions while split-thickness grafts are suitable to cover large surfaces and more quickly vascularized but are more susceptible to shrinkage.

Commonly, FT grafts are used in closure of the forearm free flap donor site while split-thickness grafts are used in maxillectomy defects under an obturator and in fibula flap donor sites.

Procedure – FT grafts are raised freehand with a knife and de-fatted on the table before applying to a defect such as the forearm flap donor site.

Split-thickness skin grafts (STSG) are raised with a dermatome set at a thickness of 0.3–0.45 mm (Figure 17.8a)

Pitfalls – Unstable dressings enabling movement of graft and haematoma collection.

Early removal of dressing and early function of donor area.

Figure 17.6 Galea aponeurotica pedicled flap turned over zygomatic arch to augment facial contour.

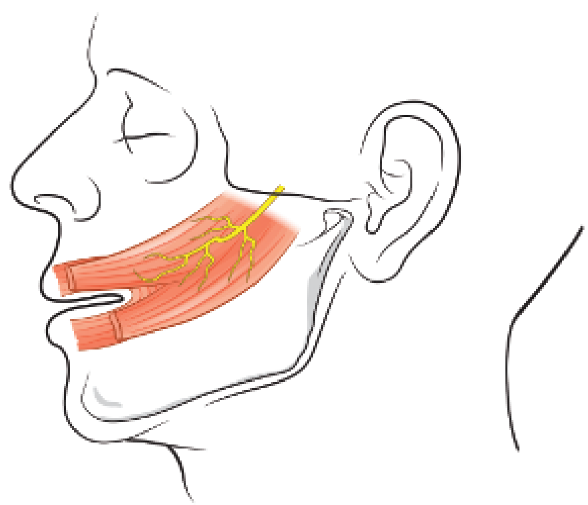


Figure 17.7 Masseter flap raised off mandible pedicled superiorly and sutured to corner of mouth for facial animation.

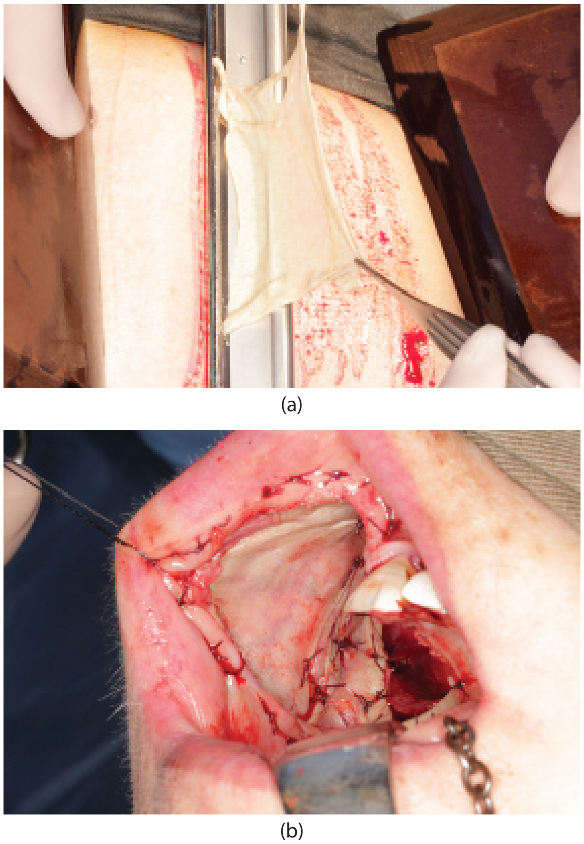


Figure 17.8 (a) STSG raised by dermatome. (b) Graft sutured to cheek defect.

MUCOSAL GRAFTING

Principles – Free mucosal grafting is indicated as an adjunct to implant rehabilitation of edentulous or reconstructed jaws. These grafts heal under specially prepared dental splints and provide a firm basis around implants or implant-supported prostheses.

Procedure – The cheek is ballooned intra-orally with a saline injection and the graft is outlined and raised with a sharp knife.

De-fatting/thinning is done on the table before insertion at the prepared site.

In the prepared site on the alveolar ridge or ridge equivalent (Figure 17.9).

Pitfalls – Inadequate (insufficient) graft requiring a second harvest attempt.

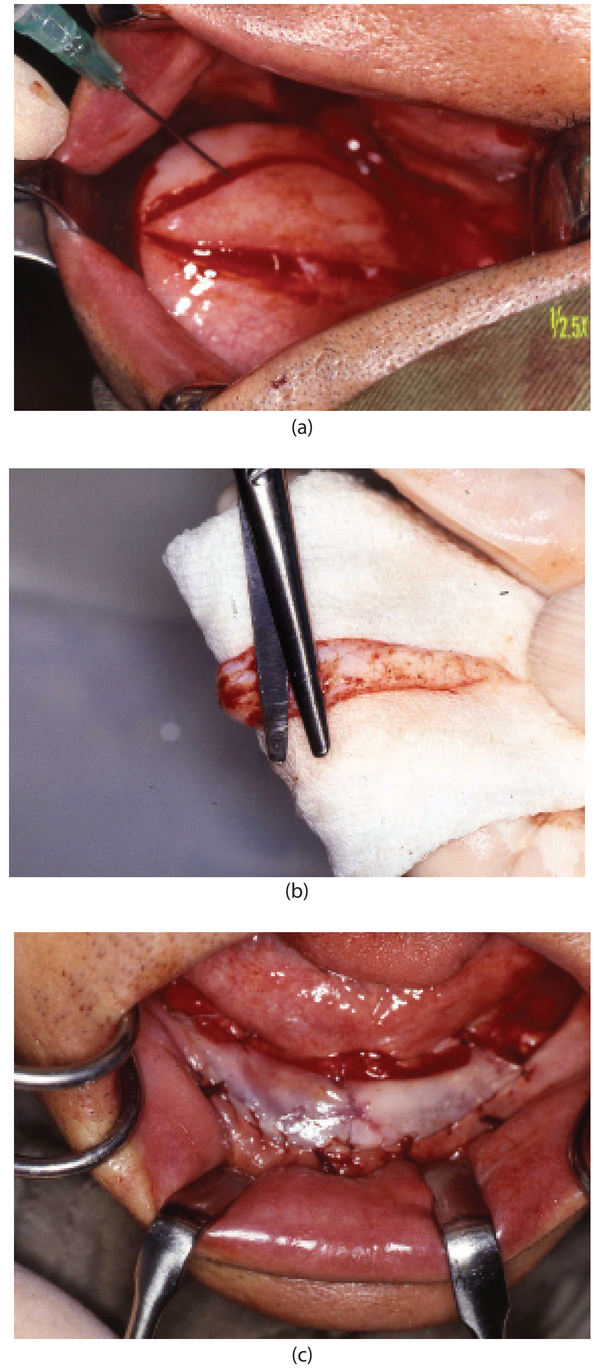


Figure 17.9 (a) Mucosal graft outlined with knife and ballooned with saline injection. (b) Graft defatted on the table avoiding perforation. (c) Graft inset in buccal sulcus.

18

Pectoralis major

ANDREW LYONS

CONTENTS

PRINCIPLES AND JUSTIFICATION

First described by Ayrian in 1979, the pectoralis major rapidly became the workhorse in head and neck reconstruction. Raised as either a myocutaneous or muscle flap, only the flap developed a reputation for a reliable easy-to-use reconstruction. It is based on vessels of the thoracromial artery. The muscle exists as two portions: a clavicular head, from its sternal half, and a sternocostal head, from the sternum to the level of the seventh costal cartilage and from the upper sixth rib. The muscle is attached by a flat tendon into the lateral lip of the inter-tubercular sulcus of the humerus.

Its blood supply is based on vessels of the thoracromial artery. This artery, on entering the deep 'clavipectoral fascia' of the muscle, splits into a deltoid branch to supply the humeral head and a pectoral branch to supply the remainder of the muscle. The pectoral potion of the muscle also gets its blood supply from the lateral thoracic artery and perforators from the internal mammary artery. Both of these vessels are almost always sacrificed to enable mobilization of the flap, as the pectoral branch is almost always the dominant vessel. However, this axial patterned flap is not without limitations and problems. The first is bulk; although the muscle bulk disappears with time, this deformity is never lost. As the muscle traverses the neck much needed cover of exposed vessels may be desirable.

Pedicle length may be a problem particularly where a myocutaneous flap is desired for a cutaneous defect. Although it is adequate for most intra-oral defects, except those where maxillary obturation is required where external skin coverage is required, pedicle length is lost as the skin flap is effectively doubled over to achieve the correct skin orientation.

The biggest problem is skin reliability although a total necrosis rate of between 3% and 7% was found, a partial necrosis rate of 29% was noted of the skin paddle.

Other operators have published better results. The paddle is usually taken at the extreme end of the flap. In the female, it is not possible to harvest skin more superiorly as the breast tissue will make the flap bulky and awkward. The viability of skin is dependent on perforators in the area that come predominantly from the pectoral branch. In the author's experience, skin will be lost in 1:10 male flaps and 1:3.5 female flaps. Fortunately, this is not usually a problem as the underlying muscle will usually obturate the defect to prevent a fistula, but this cannot be guaranteed.

Therefore, for greater safety a muscle only flap can be raised. This may cause some loss of mobility in oral reconstructions and diminish the bulk where it may require.

INDICATIONS

Many surgeons justify the use of this flap over a free flap to reduce operating time and by conjecture operative morbidity. In the author's experience, this is a fallacy. It is difficult to raise this flap synchronously unlike most free flaps, and the time taken in raising this flap is not that much less than the time taken for an experienced microvascular surgeon to complete an arterial and venous anastomosis.

It is certainly an option where previous surgery and or radiotherapy have made access to reliable vessels for

microvascular anastomosis difficult, particularly when this affects both sides of the neck. When using this flap after radiotherapy, a backup flap should always be planned to deal with the possibility of a dehiscence around part of the flap or elsewhere in the head and neck. It is certainly useful to obturate defects where a free tissue transfer has failed.

It provides a useful myocutaneous flap for larger rather than small defects as this increases the number of perforators to the skin. It can be used for large tongue and floor of mouth defects, particularly total glossectomy defects. It is useful for lateral mandibular defects where a reconstruction plate is not to be used. By conjecture, this is not a useful reconstruction for defects involving an anterior segment of the mandible where some form of spacer such as a reconstruction plate would be required. Dehiscence for plates use in conjunction with pectoralis major flaps has been recently put at 30% for lateral defects and 50% for anterior defects. It can be used as a tubed flap in laryngeal reconstruction, but leakage and dehiscence are high. If used for cutaneous defects in the neck, the reliability of the flap can be enhanced by using a myocutaneous flap and overlying this with a split skin graft. Within 3–6 months, a surprisingly good aesthetic result can be achieved.

OPERATION

Position of the patient

The patient is supine with the arm on a board and abducted to 90°. A line should be drawn from the medial tip of the coracoid process to the tip of the xiphisternum (Figures 18.1 and 18.2). This approximates to the surface markings of the pedicle; the thoracoacromial vessels. The muscle extends inferiorly to the costal margin of the fifth, sixth and seventh ribs. It is not recommended to mark or develop the skin paddle beyond the costal margin, it is surprisingly easy to incorporate parts of the rectus abdominis muscle into the flap in an effort to increase pedicle length, but this should be avoided if possible to achieve maximum skin reliability.

The skin paddle (if required) should therefore be situated on the line of the pedicle with the costal margin as its lower margin. In males, ellipsoid paddles should be orientated lengthways along the pedicle marking. In females, for cosmesis, the pedicle can be orientated horizontally in a sub-mammary position.

Incision

To access the pectoralis major, there are three basic options to access the fat and underlying pectoralis muscle.[1] The simplest is from the thoraco-acromial process in a straight line towards the lower point of the xiphoid process, stopping at the skin paddle if present, or if not until the lower border of the pectoralis muscle is easily visualized (Figures 18.1 and 18.2). From the top of the anterior axillary line,

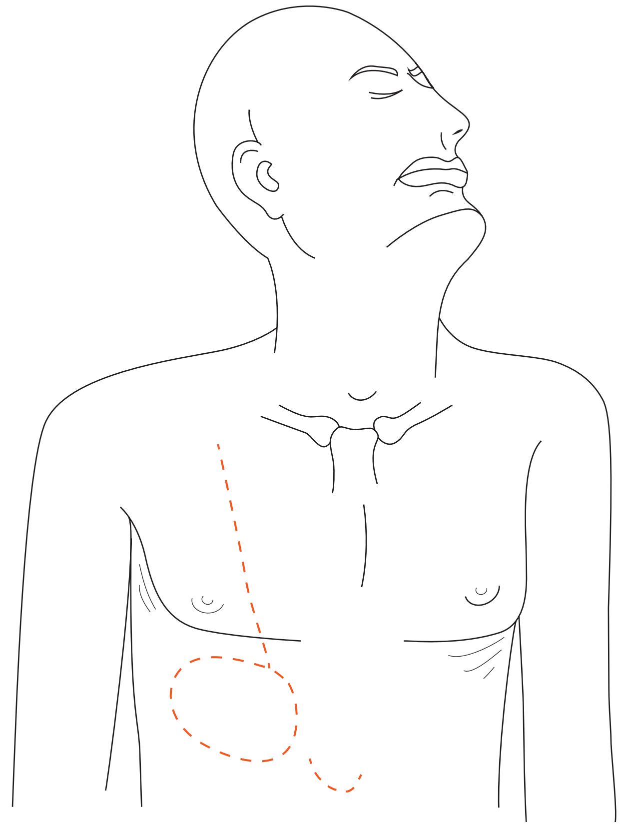


Figure 18.1 Surface markings for thoracoacromial vessels, incision and flap.

Figure 18.2 Surface markings for thoracoacromial vessels, incision and flap (photo).

a sub-mammary incision is developed (Figure 18.3). The incision in 1 is used but begins on the deltoid muscle having a superior horizontal margin that is effectively the lower border of a deltopectoral flap, enabling this to be used. This is known as the defensive incision (Figure 18.4). The skin paddle should be incised through subcutaneous fat to the underlying muscle. To increase the number of perforators, a layer of subcutaneous fat can be raised along the length of the muscle pedicle (Figure 18.5) and this will mean at the superolateral aspect of the skin paddle. The incision passes only down to the subcutaneous fat. However, this still does not guarantee success of the skin layer and, as the pedicle passes directly below the breast, at least some subcutaneous fat should be left in females.

Raising the flap

The skin paddle having been defined, the muscle should be dissected off the underlying chest wall. Although it is less well-defined inferiorly, a plane can be developed on the surface of the rib periosteum and the fascia over the inter-costal muscles. Proceeding first in a superolateral and then lateral direction, dissection and elevation of the flap can begin. Laterally, it should be easy to palpate and see the lateral border of the muscle. During the dissection, perforators will be encountered running into the muscle from the chest wall. They can usually be left on the muscle but those on the chest wall should be diathermized.

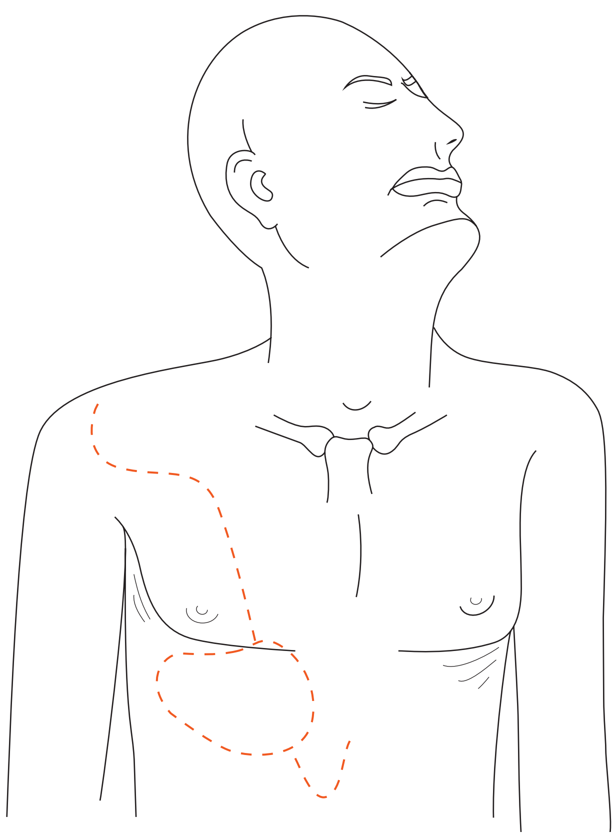


Figure 18.3 Surface markings for a defensive incision.

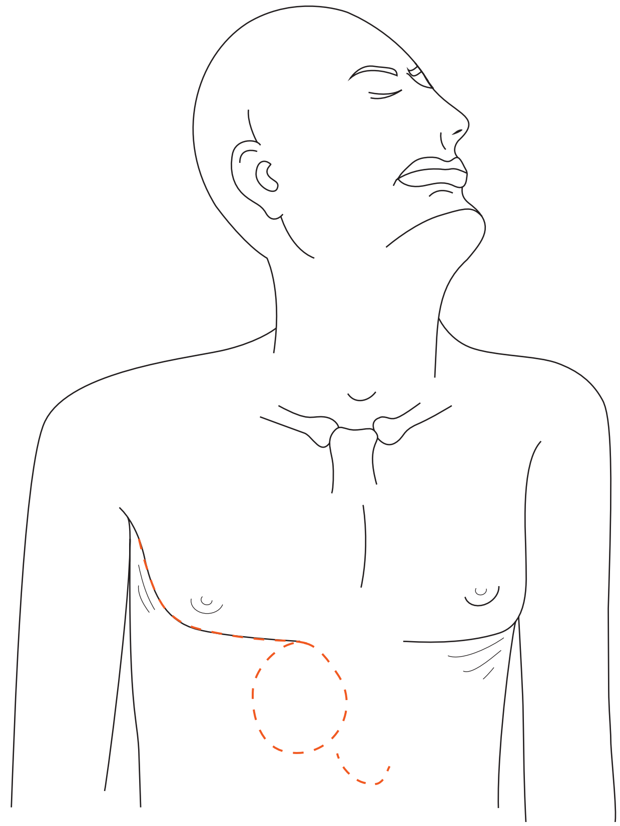


Figure 18.4 Surface markings for a sub-mammary incision.

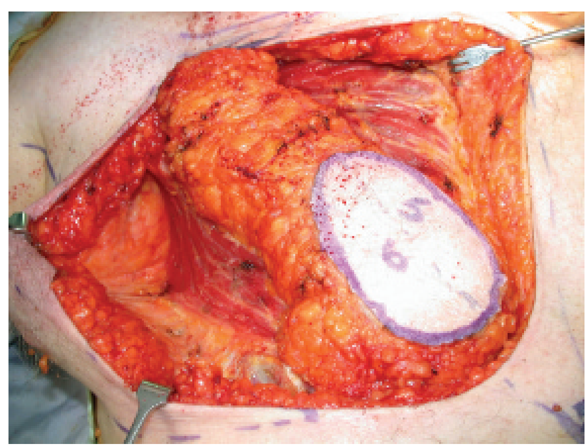


Figure 18.5 To increase the number of perforators, a layer of subcutaneous fat can be raised along the length of the muscle pedicle.

Exposure of pectoralis minor

As the muscle is dissected off the chest wall midway, the pectoralis minor will be encountered (Figure 18.6). This muscle should be spared and is separated from the pectoralis major by its fascia. At this stage, the pedicle should be visible through a thin layer of fat below the pectoralis major muscle (Figure 18.7). At the lateral part

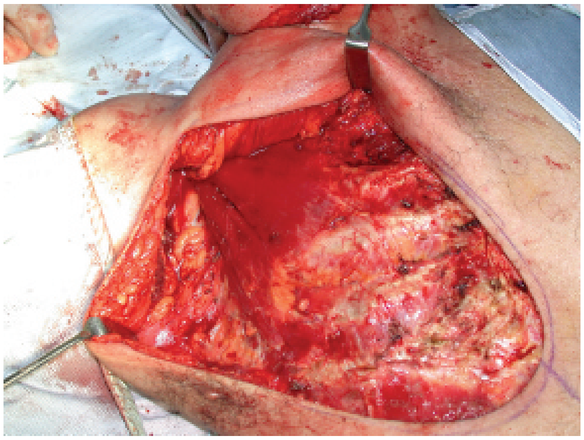


Figure 18.6 As the muscle is dissected off the chest wall midway, the pectoralis minor will be encountered.

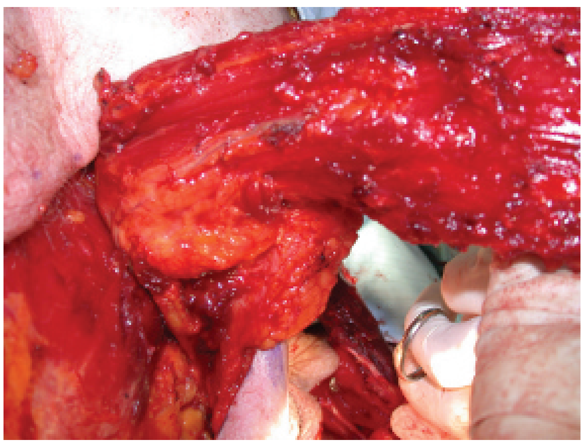


Figure 18.7 The pedicle should be visible through a thin layer of fat below the pectoralis major muscle.

of the dissection, the antechostal brachial nerve will be encountered and should be divided. Just above this are the lateral pectoral vessels. Unless the flap is required for the lower neck, providing the thoracoacromial vessels have been identified, these should be divided as its integrity will restrict the vertical movement of the flap.

If the thoracoacromial vessels have not been visualized at this stage, the dissection should proceed no further, as the thoracoacromial vessels are laterally disposed beneath the muscle and can conceivably be confused with the lateral pectoral vessels. Having divided the vessels, it will probably be necessary to diathermy muscles in the axillary fat. At this stage with the pedicle visualized, the humeral head should be divided in the axilla and this will add considerable length to the flap.

Elevation of the flap is almost complete and should proceed upwards to just below the clavicle if necessary, which in most cases, it will be to ensure adequate pedicle length.

Making the tunnel

A tunnel should be made above the clavicle and below the skin and subcutaneous tissue into the neck (Figure 18.8). This is usually achieved by dissecting downwards from the neck and upwards from the donor site wound. The space within this tunnel can be assessed by inserting the four fingers of a hand. Recently, the supraclavicular flap based on supraclavicular artery and vein a branch of the transverse cervical artery that enters the subcutaneous fascia from the subclavian vessels approximately at the point of the medial third of the clavicle. By visualizing these vessels and then preserving them during tunnel formation, a supraclavicular flap will still be a possibility, after transposition of the pectoralis major flap.

The upper border of the skin paddle or lower border of the muscle should be grasped from above by a large clip after its insertion through the tunnel and then pulled gently upwards. If resistance is encountered, the tunnel and pedicle should be reassessed to see where there is snagging. Some surgeons suture the edges of the skin paddle to the muscle below to prevent shearing of the skin paddle. In the author's opinion, this is unnecessary if the flap is handled with care and respect.

Insetting the flap

When the flap has been placed in situ, it must not be under any tension. Not only might this affect the flow within the pedicle, but over the next 2 weeks as the muscle scars and contracts it will pull the healing wound edges away inferiorly leading to wound dehiscence. The flap can reach further if muscle only is used, but again lack of tension is vital. The flap should be secured with muscle, subcutaneous and skin layers.

The donor site can usually be closed primarily (Figure 18.9) and the cosmetic result is particularly good after a submammary incision in females (Figure 18.10). Suction drainage is recommended, particularly in the axilla.

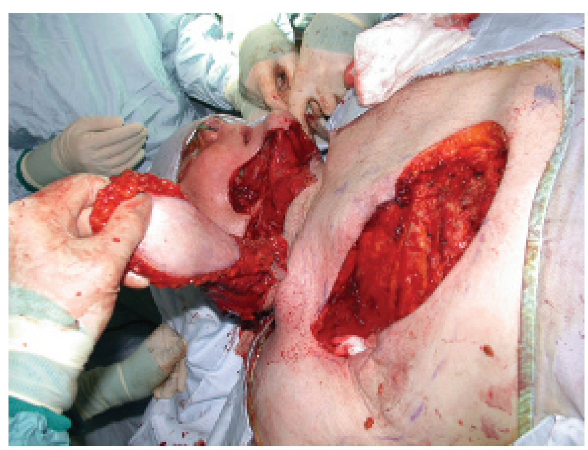


Figure 18.8 A tunnel should be made above the clavicle and below the skin and subcutaneous tissue into the neck.

Figure 18.9 Primary closure of incision in Figure 18.2, showing inset of flap into neck.

Figure 18.10 A healed sub-mammary incision showing its invisibility.

POST-OPERATIVE CARE

Monitoring is less crucial than free tissue transfer. Twice a day should suffice as little can be done to correct any apparent arterial or venous problem, and certainly in the immediate post-operative phase, pallor and the colour and quantity of blood on pinpricking are unreliable.

COMPLICATIONS

Intra-operative

The pedicle may be damaged during flap elevation.

Post-operative

- Flap necroses: It is extremely unusual, though not impossible, for the entire flap to become ischaemic and necrose.
- Partial necroses: More commonly, this applies to the skin and subcutaneous fat. If this occurs intra-orally, a leak into the neck and fistula formation are not inevitable in the presence of viable muscle. The dead tissue should be debrided and, if carried out in an operating room, local anaesthetic may be an option in patients who are not SA 1.

Top tips

- Leave the subcutaneous fat along the line of the pedicle to increase the number of perforators supplying the flap.
- In women, always use a sub-mammary incision and avoid taking too much fat with the flap.
- If replacing external skin in the neck, using a split skin graft over a muscle only flap will increase flap length and reliability. In time, a very acceptable result will be obtained from the skin graft with less donor site morbidity.
- Always plan at least one backup flap either deltopectoral or supraclavicular when operating after radiotherapy in case of a non-healing dehiscence.

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19

Reconstructive surgery – Harvesting, skin mucosa, bone and cartilage

PETER A BRENNAN

CONTENTS

SKIN

Indications

Other than for burns, which are beyond the remit of this chapter, the most common requirement for replacing skin in the head and neck region is after removal of large skin cancers. Skin grafts can be particularly useful in areas such as the scalp where for large defects local flaps do not often provide enough skin for tension-free closure. Furthermore, some scalps have very little 'give' resulting in difficulty closing defects with scalp-based local flaps. In some third world countries, skin is used for replacement of oral mucosa, but this technique is rarely used in the western world with modern techniques including local and distant flaps being readily available. Skin grafts may also be required to close donor sites following free flap harvest, with examples being the radial forearm free flap (Figure 19.1) and for large anterolateral thigh flaps.

Surgical options

There are a variety of options for closure of cutaneous defects, each having advantages and disadvantages (see Table 19.1).

Surgical technique

See Figures 19.2 through 19.6.

Direct skin closure

This is best achieved by using an elliptical incision that is placed in Langer's lines. Skin becomes more lax with age and certain areas such as the cheek, neck and temple region may be suitable for direct closure following excision of a lesion. Ideally a 3:1 length to width ratio is used, which can be marked pre-operatively. The skin incision should be made at right angles to the skin itself to avoid shelving and local undermining of the surrounding tissue will allow for a tension-free closure. With direct closure, a two-layer suture technique is useful, so as to take off as much tension on the skin sutures. For the deeper layers, a resorbable suture such as 3/0 or 4/0 Vicryl or 4/0 Maxon (the author's preference), ensures the skin sutures ideally 5/0 non-resorbable monofilament sutures such as Ethilon, Prolene or Novafil.

Local flap closure

While local flap repairs are covered elsewhere in this book, there are certain surgical principles which are common to all. The local flap can be either 'advanced' or 'rotated' into the defect (see Figures 19.7 through 19.10). Some also consider the transposition flap as a separate category, but this is usually a variation of rotation and/or advancement (Figure 19.11a through c).

The following are the key principles of local flap surgery:

- The skin of the flap should be from within the same aesthetic zone.
- The final scar should, as much as possible, lie along lines of tension, but this is rarely possible with all the incisions.
- The choice of flap is dictated by seeking tissue from an area of lax tissues. Thus, the decision as whether to rotate or advance is based on the site of the lesion and the site of available tissue.
- On the face, the flap length to width ratio should be no more than 4:1 for fear of compromising the blood supply.

Figure 19.1 Excellent result with skin graft to radial forearm flap donor site.

SKIN GRAFTING

The two types of skin graft are full-thickness (which includes the underlying dermis) and split-thickness grafts, which should ideally be at a depth (often about 0.15–0.2 mm) to cut across the rete pegs to enable healing. Full-thickness grafts can be harvested from the lax neck skin, post-auricular region or for larger defects, the abdomen.

Full thickness (Wolfe graft)

The following are the key points to remember for the donor site (see Figures 19.12 and 19.13):

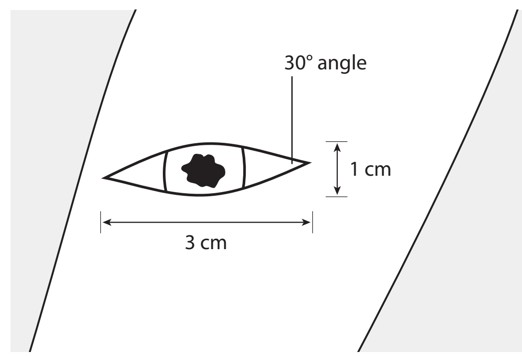


Figure 19.2 Direct closure; the ratio of length to width should be 3:1 and create 30° angles.

Table 19.1 Surgical options.

Procedure	Advantages	Disadvantages
Direct closure	Incision lines can be kept along the lines of natural tension, improving aesthetic outcome Using local skin from the same aesthetic zone	Limited defects only, as closure will create excessive tension leading to wound breakdown and infection
Local flap harvest – advancement	Allows much larger lesions to be closed	Unlikely that all the skin incisions will run along natural tension lines
Rotation procedures	Usually can be raised from the same aesthetic zone	
Skin graft – full thickness	Large area of skin can be covered Better aesthetics, in terms of thickness of the graft and aesthetic skin match than split skin but not as good as local flap	Problems of a donor site, produces a second area of scarring Poor skin colour and thickness match Takes 10–14 days to heal
Skin graft – split skin	Almost limitless amount of skin in terms of the head and neck	Very poor skin, texture and thickness match Painful donor site Both sites take 10–14 days to heal Significant wound contraction, about 20%
Skin – free tissue transfer	Large area No delay in healing Usually possible to get the correct thickness	Long surgical procedure Poor colour and texture match

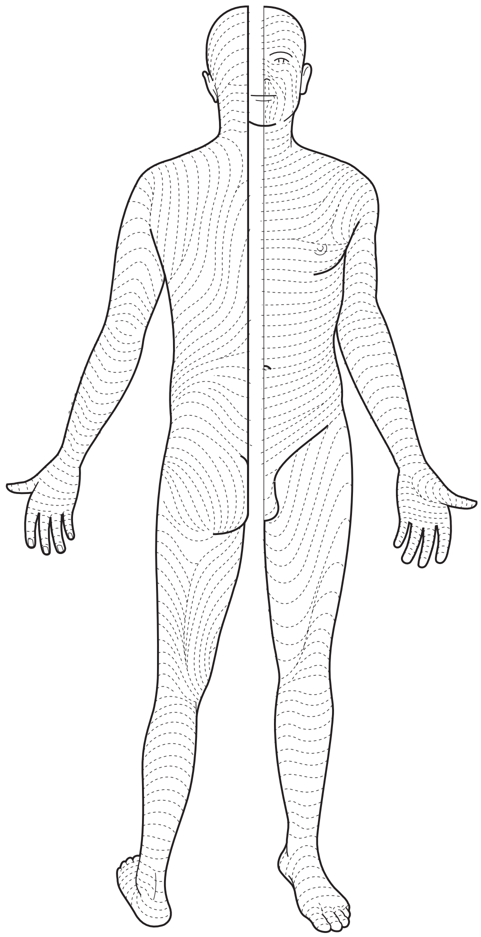


Figure 19.3 Incisions along the lines of tension, as shown, create narrow scars. Crossing these lines produces a broad ugly scar.

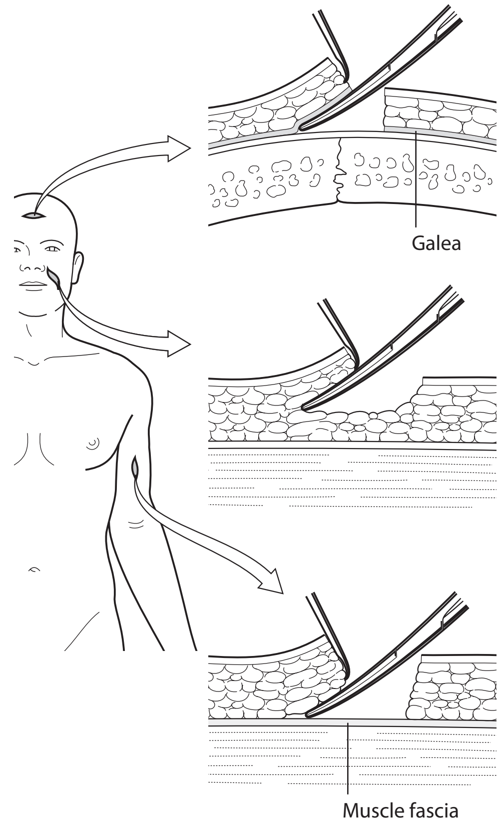


Figure 19.5 Undermining of the tissues should be in the subcutaneous level and only about 1 cm distance. Sharp dissection is better but may induce more bleeding than blunt dissection.

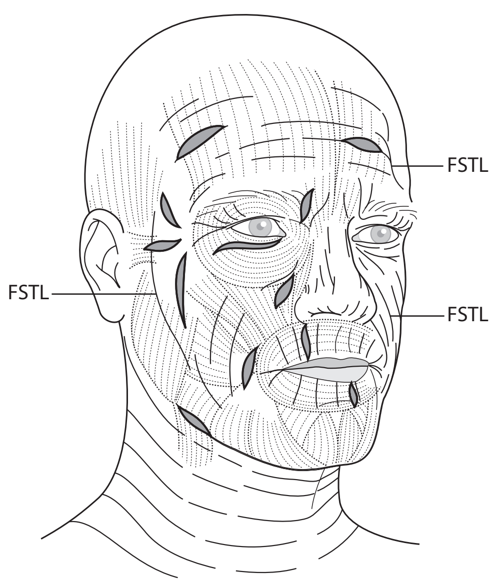


Figure 19.4 These tension lines are even more important in the facial region. FSTL, favourable skin tension lines.

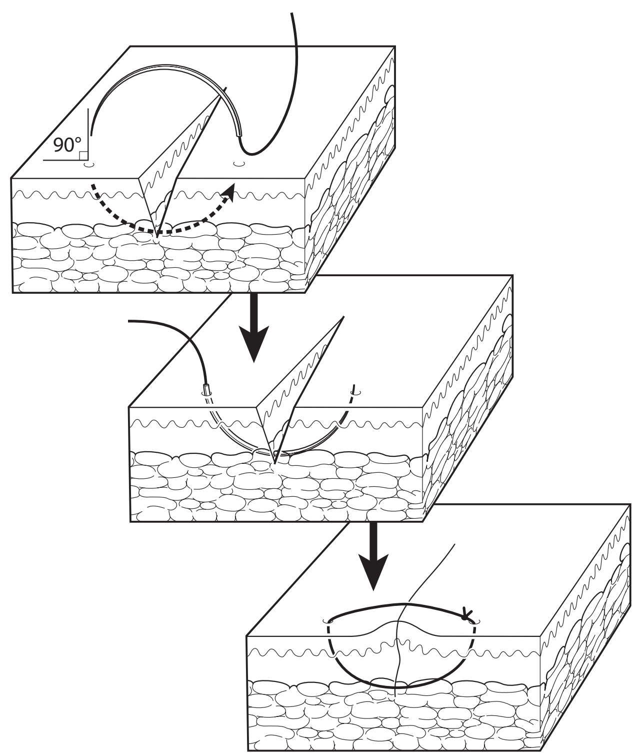


Figure 19.6 Careful suture and creating skin eversion is essential.

- Sufficiently lax to provide enough skin and enable primary closure of the donor site
- Provide good colour and thickness match (ideally use head and neck skin where possible rather than abdominal skin to help with colour match)
- Not in an obvious visible site or placed in a skin crease (for example neck skin harvest)

Donor sites: In practical terms, the following donor sites are frequently used:

- Root of the neck: This can often provide up to 4–6 cm grafts, and can be hidden in a skin crease and the scar can be covered by clothing. The skin is thinner than that of the abdomen.
- Post-auricular: The biggest issue with this site is the limited size of graft that can be obtained (usually no more than 2–3 cm in width). The scar is hidden and the colour match can be good. It can sometimes cause the pinna to be pulled back. It is not easily seen. The skin is thin with good colour match.
- Pre-auricular: This provides a good colour and texture match for the facial skin but as with the post-auricular harvest site, is limited by width.
- Abdomen: A large graft can usually be taken from the lower abdomen and hidden in the underwear line. These grafts are particularly good for larger defects (such as large scalp lesions).

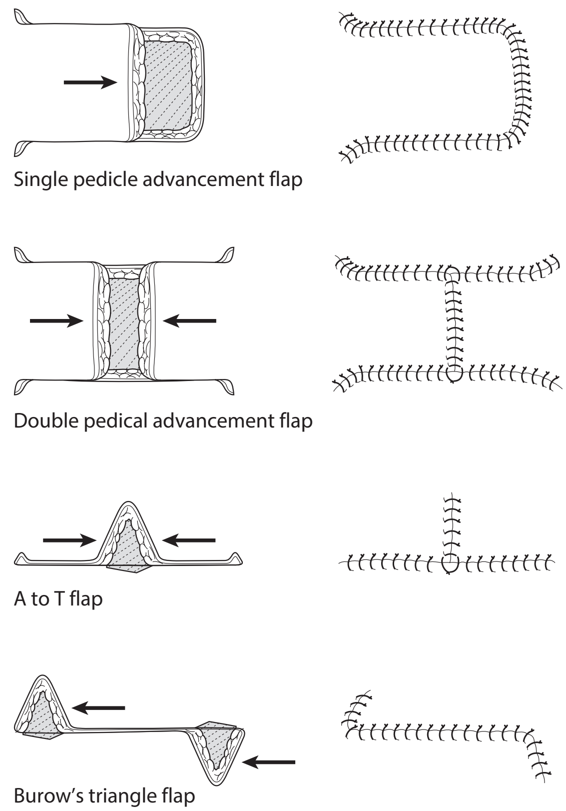


Figure 19.7 The principles of an advancement procedure.

Technique

The graft can be harvested under local or general anaesthesia, and is usually marked on the skin to reflect the size needed. It should be marked as an ellipse to enable primary closure. The two end parts can be subsequently removed. The skin is excised in to the underlying subdermis/fat using a scalpel or cutting diathermy. It is important to have meticulous haemostasis at the excised site to allow intimate contact between the skin graft and wound bed – small stab perforations in the graft are ideal for this. The harvested graft should be de-fatted using scissors and the donor site should be closed in a two-layer technique. For a large graft, a small suction drain for the first 24 hours is often useful.

Once the skin graft is secured in place, either by fine resorbable sutures such as 5/0 Vicryl, while some advocate cyanoacrylate glue, dressings should be firmly placed over the graft to oppose it to the wound bed. Silicone mesh covered

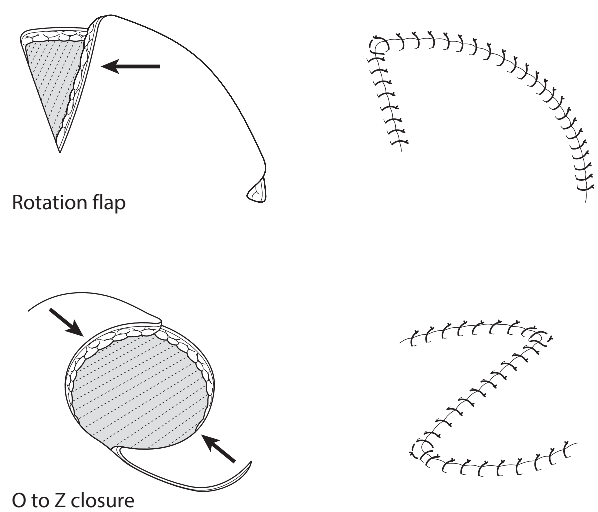


Figure 19.8 The principles of a rotation procedure.

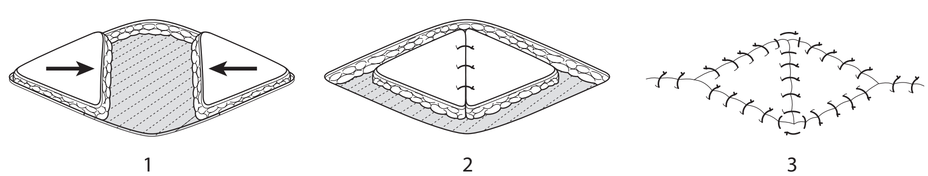


Figure 19.9 Island flaps rely on the subcutaneous tissues for their blood supply, so the rotation or advancement is over a short distance, lest the tension will impair the blood supply.

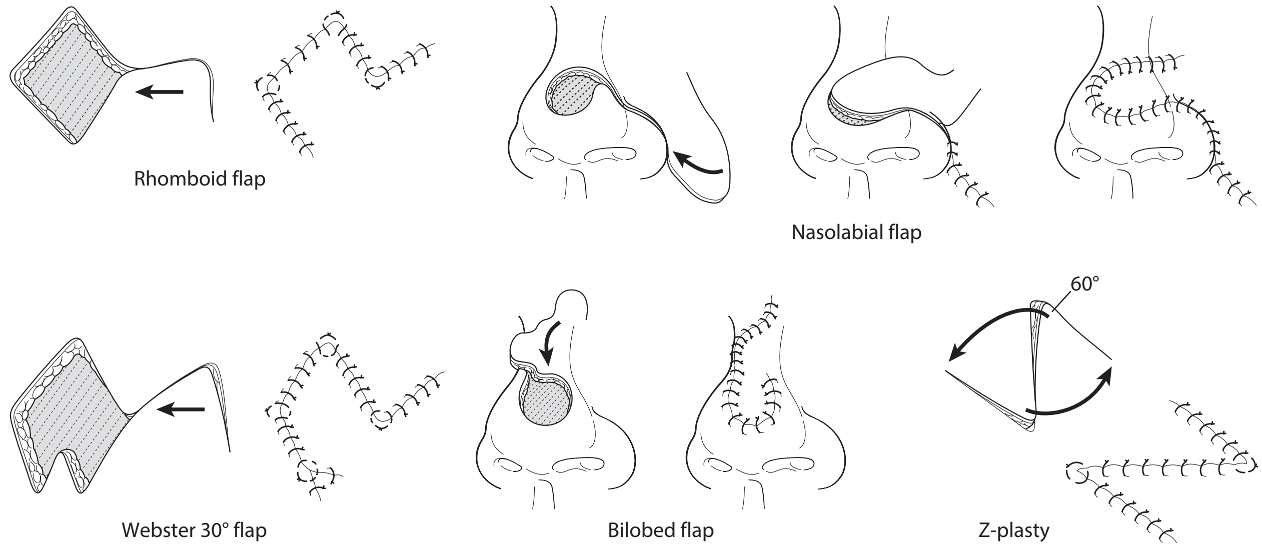


Figure 19.10 Different examples of rotation procedures.


(a)


(c)


(b)

Figure 19.11 (a–c) Transposition flap in the right temple area showing marking, flap raised and post-operative appearance (labelled as transposition flap 1 and 2 and post-operative appearance).

by proflavine-soaked cotton-wool dressing or a foam dressing all secured by tie over sutures or staples are ideal.

Pain is not usually a feature of the donor site (unlike a split-graft harvest).

The wound at the surgical site should ideally be left undisturbed for 10 days, although it should be regularly inspected to check for haematoma and wound infection.

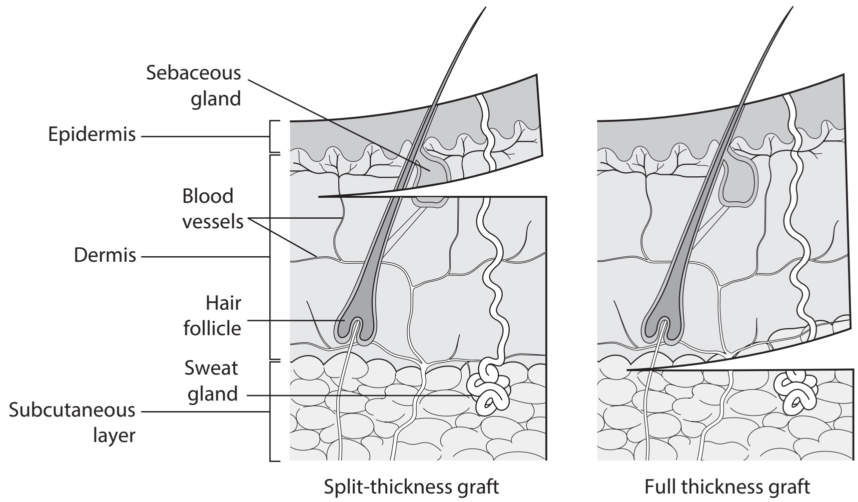


Figure 19.12 The differences between spilt- and full-thickness grafts.

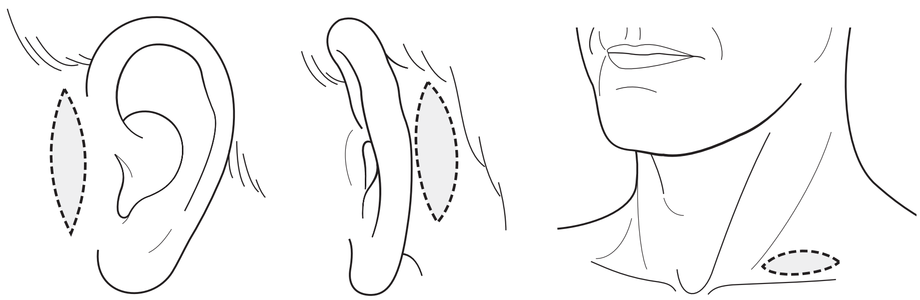


Figure 19.13 Good sites for full-thickness grafts.

Split skin grafts

Any part of the skin is a potential donor site for a split skin graft, but ideally a flat surface which is not too visible and has adequate dimensions means that the anterior or inner aspects of the upper thigh or upper arm are usually used (ideally the non-dominant arm). These harvest sites do not immobilize the patient, normally has enough skin, is easily kept clean and can be readily observed (see Figures 19.14 and 19.15).

Technique

- Topical cleaning prior to and after surgery may be helpful, but the routine use of antibiotics is not indicated.
- Meticulous haemostasis is needed to ensure good contact between the graft and the nutritional wound bed.
- Firm pressure to stabilize the graft and prevent a haematoma forming beneath the graft. A similar dressing technique as used with a full-thickness graft is ideal.
- Again, stab perforations or meshing of the graft helps to prevent haematoma formation.
- Ideally the wound should be left untouched for 7–10 days.

The thinner the graft the more likely it will form a blood supply but the greater the contraction. Normally, the graft should be about 0.2 mm, which is about the thickness of a No. 15 scalpel blade.

The skin can be harvested with a conventional hand-held instrument (Humby knife), but it is very difficult to get an even thickness and the edges can be serrated. The standard traditional skin-grafting knife has more or less been replaced by either an electric- or air-powered dermatome. This produces a very even-thickness graft, but more importantly the width of the graft can be more easily predicted. The success of the technique is very much related to acquiring the experience to get a good 'feel' for the depth of the cut. However, certain techniques can make it more predictable, and the author routinely sets the blade depth to 0.2 mm using a No. 15 scalpel blade.

- The skin and cutting surfaces should be well lubricated.
- A flat board should be advanced just in front of the dermatome to ensure a flat surface is presented to the blade. Slow even progression of the dermatome prevents folding of the skin ahead of the blade producing a more even cut.
- Meshing of the graft can increase the size of the graft by about 30% but in most cases the meshing is merely to create small perforations to prevent haematoma formation.

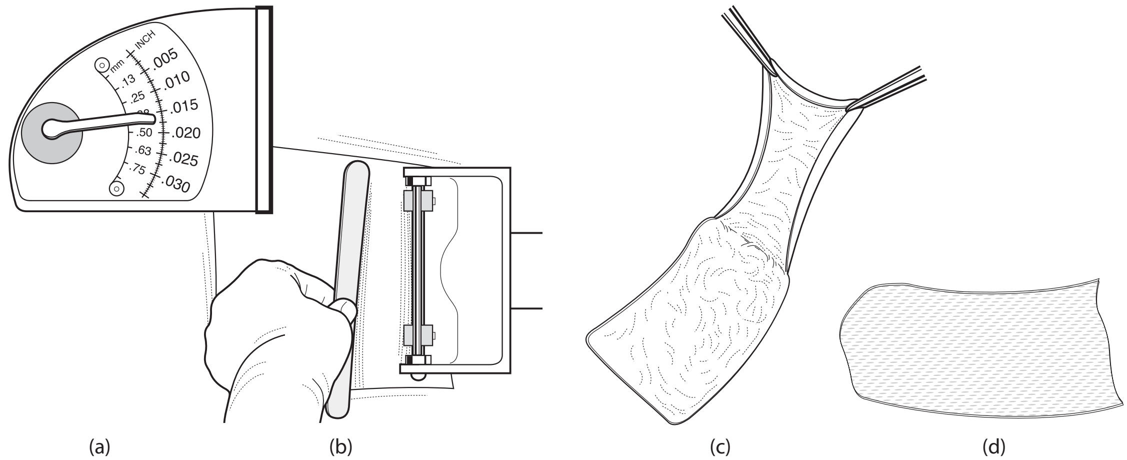


Figure 19.14 The stages of split skin grafting: (a) setting the correct thickness, the width of a No. 15 blade is a good guide; (b) the area must be well lubricated and the piece of wood just ahead of the dermatome ensures an even thickness across the whole width of the cut; (c) typical appearance and (d) the graft should have small perforations to prevent haematoma formation.

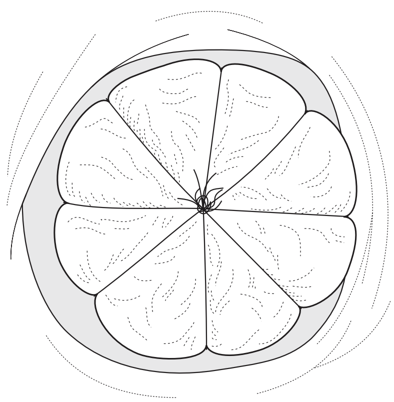


Figure 19.15 Tie over sutures maintain stability and prevent haematoma under the graft.

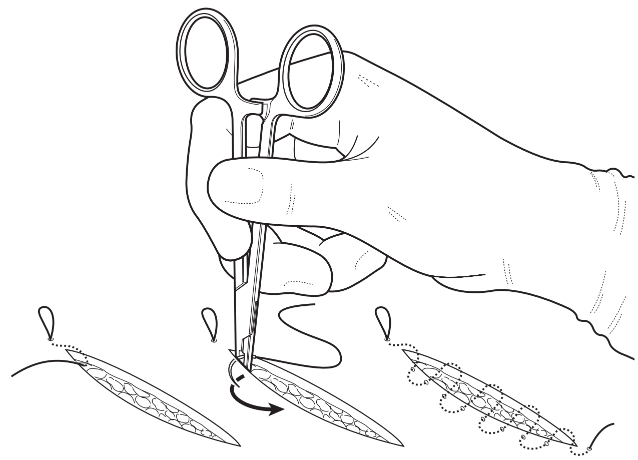


Figure 19.16 Subcuticular sutures are easy to remove than interrupted sutures and may help to prevent 'stitch' marks if a resorbable suture is used.

The donor site can be extremely painful and this must be anticipated and prevented. A commonly used technique is to apply an alginate-soaked dressing (such as Kaltostat) impregnated with long-acting local anaesthetic, such as 0.5% buvicaine. Regular systemic analgesia is also useful. The alginate dressing is then, and importantly, stabilized with an adhesive dressing such as Opsite or Tegaderm™. The wound should be left untouched for 14 days. It is essential to keep the wound under observation to check for haematoma formation or infection as the wound may need to be exposed and cleaned up.

Free tissue transfer is covered elsewhere in the textbook.

CHOICE OF SUTURE MATERIAL

Resorbable suture materials are in theory highly desirable, since they avoid the often uncomfortable removal for the patient. Unfortunately, these materials have a number of problems on the skin itself, in that they excite a foreign body reaction, producing significant inflammation. They are of course very useful to reduce tension and aid skin closure in the deeper tissues.

When used on the skin surface itself, the resorption process is too slow for facial wounds, as the material should have disappeared within 5–7 days. Fine resorbable sutures (such as 5/0 and 6/0 Vicryl rapide) can be very useful in some clinical situations (such as in children) but these are braided and their resorption is not entirely predictable. The use of resonrbable subcutaneous sutures with cyanoacrylate glue is another option for children. Suturing technique including, removal of a dog ear, is shown in Figures 19.16 through 19.18.

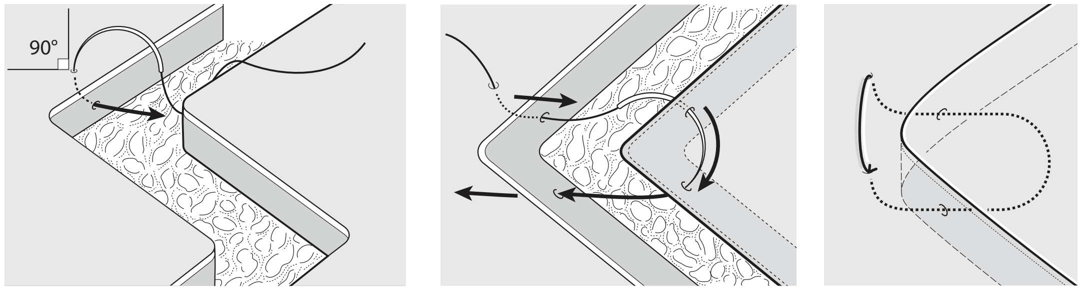


Figure 19.17 This avoids the pressure of the suture causing necrosis of the tip of such a sharp angle incision.

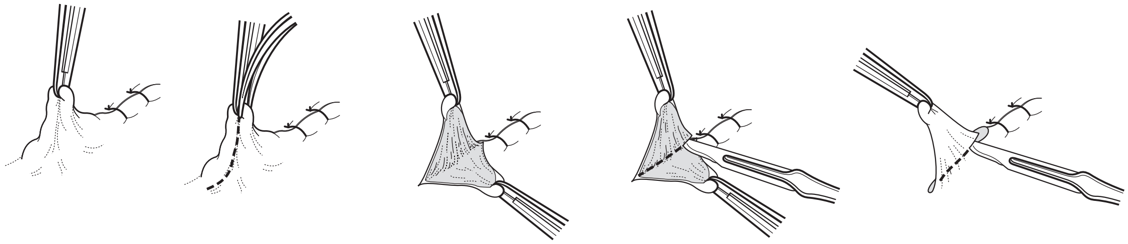


Figure 19.18 Removal of a ‘dog ear’.

The ideal material is a non-resorbable monofilament material (e.g. Ethilon, prolene or Novofil – the latter being the author’s choice, also having a good suture needle). These materials have minimal tissue reaction and can be removed at 5–7 days.

ORAL MUCOSAL FLAPS

As with the skin, these flaps can be directly closed, or be taken as local rotational and advancement flaps. As with skin flaps, excessive tension will reduce the blood supply and lead to dehiscence and infection and the flap length/width ratio should be no more than about 4:1 (see Figures 19.19 and 19.20).

The only non-muscle flap with a true vascular pedicle is based on the greater palatine vessels, the rest are random pattern flaps. Unlike skin, the local anatomical variations of the mucosa demand special attention. For example, it is most important that attached mucosa is attached to the gingiva of the teeth so flaps must be designed to ensure that relationship is maintained.

In some cases, this is not possible and free full thickness attached mucosa, normally harvested from the palate may have to be used. A micro-dermatome is an excellent way of achieving such a harvest.

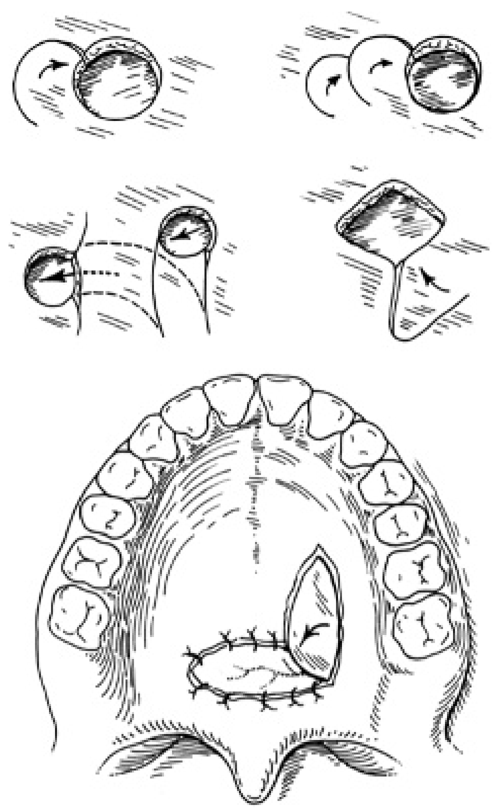


Figure 19.19 Posterior view of the right shoulder showing the blood supply to the trapezius muscle and spine of the scapula.

NON-VASCULARIZED BONE HARVESTING

Non-vascularized bone grafts do not survive once transplanted, but provide growth factors and a hard tissue skeleton, stimulating angiogenesis and ultimately facilitating new bone formation. This process takes time and it is essential that the graft is placed in a highly vascularized environment free from any infection. In practical terms, bone grafts in the mouth need to be in a sealed

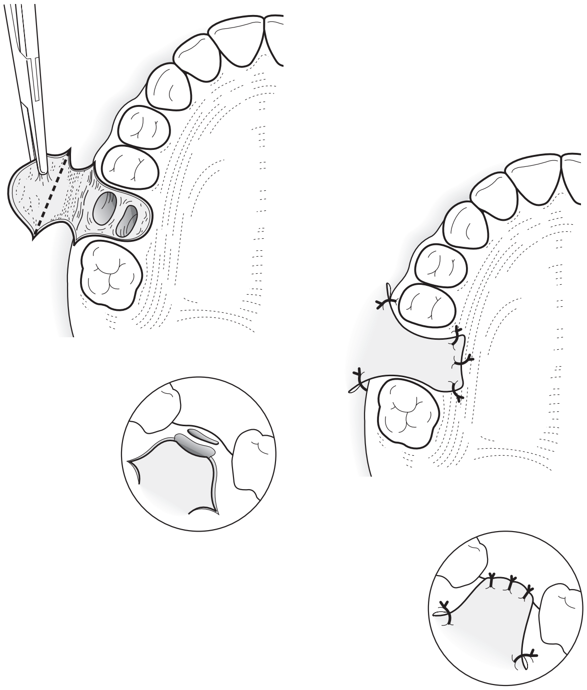


Figure 19.20 Lateral advancement flap for closure of an oro-antral fistula. In this case, the periosteum is cut gently to give much greater laxity to the overlying mucosa enabling closure.

environment with good vascularized mucosa covering the graft. Clearly, in young growing children this is most readily achieved but in elderly patients who smoke and have significant comorbidity (such as osteoradionecrosis), it is difficult to achieve. Free vascularized tissue transfer is often indicated in these patients. If, however, the patient is young or the defect is small and easily and quickly becomes re-vascularized, a free non-vascularized graft may be used (Figure 19.21).

The surgery for vascularized free tissue transfer is discussed elsewhere.

Indications

As mentioned earlier, non-vascularized bone grafts have some use, with the literature, particularly from the third world, still widely advocating their use, primarily in surgical centres which do not have access to microvascular techniques.

The main indications for free non-vascularized bone grafts are as follows:

- Alveolar bone defects in children with a cleft lip and palate.
- Small defects in the jaws, whereby the bone defect is surrounded by bone walls except at the surface (e.g. after removal of a benign tumour from the alveolus).
- Small bone defects in which an implant is to be placed (such as an atrophic ridge or where the maxillary antrum is very low).

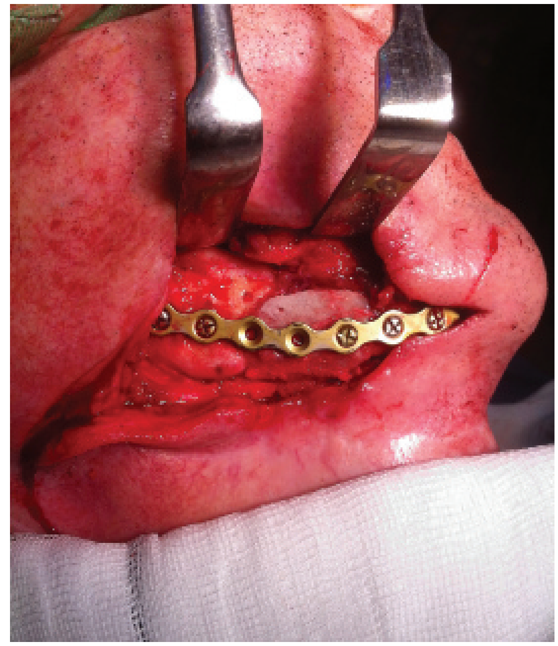


Figure 19.21 Iliac crest bone graft for small mandibular defect.

- Post-traumatic grafting to for example an orbital floor or nose.
- Secondary jaw reconstruction of small continuity defects, in which the fragments have been stabilized by bone plates. Again only small defects in patients with good overlying soft tissues are likely to be successful.

Common donor sites

A few sites are commonly used for bone harvest (see Table 19.2).

Surgical Techniques

Cranium

Bone may be harvested at the time of bicoronal flap or an incision can be made over the parietal bone prominence with care being taken to avoid damaging hair follicles (see Figure 19.22).

The incisions are taken down to the bone, and the periosteum is elevated. The outline of the bone graft is cut in the outer Table and, either with a very thin flexible oscillating saw or small curved chisels, the outer plate is raised. In children it may be helpful to do a pre-operative computed tomography (CT) to ensure adequate bone thickness. In some circumstances, if working with neurosurgeons, the full-thickness grafts can be taken and repaired appropriately.

As the bone is very rigid and hard, it has to be fashioned with cuts and bending forceps to the desired shape. It may be necessary to grind the bone to produce small fragments to pack around the main graft and produce a smooth contour at the recipient site.

Closure usually requires a small vacuum drain and should be in layers.

Rib

The incision is in the submammary area, usually 5–7 rib, but no more than two consecutive ribs should be harvested, to prevent a flail segment.

The incision is usually made in the mid-clavicular line unless a costochondral graft is needed, when it is made more medial. The incision is down to bone and a careful circumferential subperiosteal dissection is carried out using a curved stripper or Doyen. If cartilage is to be harvested, then a small layer of periosteum is left intact to hold the cartilage to the bone. Care is needed to remain in the subperiosteal plane to prevent pleural damage. The rib is cut with care to avoid damaging the pleural lining. Once removed, the cavity should be filled with saline and the chest inflated by the anaesthetist to look for any air bubbles (implying a leak). Closure is made in layers with a vacuum drain placed for 24 hours. It may be helpful to inject long-acting local anaesthetic (such as 0.5% bupivacaine) into the overlying muscle after deep closure to help with pain relief (see Figures 19.20 through 19.23).

Iliac crest

The anterior approaches are the most common graft site (see Figures 19.24 through 19.27). The incision is outlined after having marked the anterior superior iliac spine (ASIS) (Figure 19.24). The approach is deepened through the soft tissues (Figure 19.25) and down to the iliac crest (Figure 19.26). Once down to bone, either the lateral or medial tissues should be elevated depending on which surface is to be harvested. On most occasions, it will be the medial side, since less muscle stripping is needed and it is said to be less painful. The bone cuts should be made so that most of the crest remains intact.

This is done by elevating the crest and hinging it laterally, so allowing access to the bone for harvesting, and then returned once the harvest is complete. In some circumstances, if only a thin piece of bone is needed, two-thirds of the crest can be preserved and a thin slice of

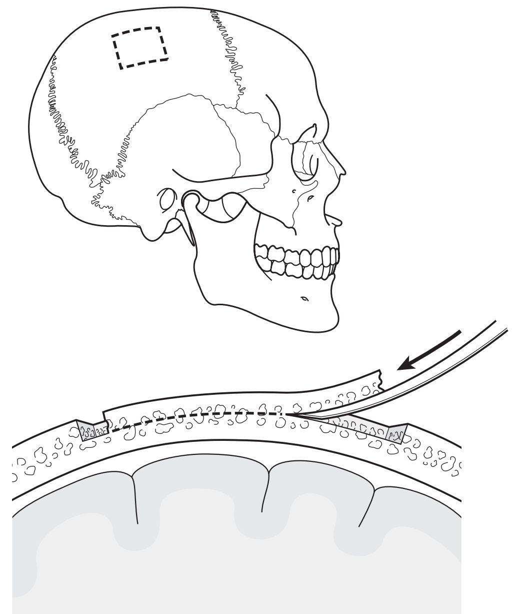


Figure 19.22 A groove is scored through the outer table and the outer table is removed with fine chisels.

Table 19.2 Common donor sites.

Site	Indications and disadvantages
Cranium, outer cortical plate	Hard stable bone, scar normally hidden in the hair. Difficult to carve and manipulate. Reported risk of precipitating intra-cranial bleeding. Small volume.
Rib with or without costal cartilage	Small volume, very soft but pliable bone. With the cartilage in 30% of cases harvested in young children it will continue to grow. Small risk of chest complications especially in the elderly, pneumothorax and chest infection. Can be painful. In young females, the harvesting may, if too high, damage breast development
Ilium anterior approach	One of the commonest sites yields large volumes of bone (especially with the posterior approach), it has an unobtrusive scar. While it is very painful, unless a trephine is used, it has few significant side effects. Damage to the lateral cutaneous nerve of the thigh should be easy to avoid, but it does happen and is a significant problem. Fractures of the iliac crest can occur. The posterior approach is much less frequently used as it is necessary to rotate the patient prevent synchronous surgery to the mouth and bone harvest.
Tibia	This is a trephine approach which yields small volumes but ideal for alveolar defects. Few complications and little pain, but unrewarding in elderly patients as the bone is replaced by fat and blood.
Intra-oral – used predominately in implantology where small volumes of particulate bone are required	Chin: easily accessed, small volume, quite vascular, but leaves anterior teeth numb for some time Lateral posterior mandible: better volume, ideal for alveolar augmentation for implants. Little visible bone defect, haematoma may produce swelling. Cortical bone scarification. This involves paring off the cortical surface of the lateral mandible. It produces a good volume of particulate bone, ideal in implantology, but no value for continuity defects, unless very small.

medial bone removed (Figure 19.27), if for example an orbital floor is being grafted. The iliac crest if temporarily hinged laterally, should be kept attached to periosteum to preserve the blood supply and stability to the replaced crest.

Supplementary fixation is not normally needed. Prior to closure, an epidural catheter should be placed beneath the muscle so a perfusion of long-acting local anaesthetic can be established for the first 24 hours for pain relief (Figure 19.28). The use of suction drains is controversial. If the drain is placed on the cut bone surface it seems to

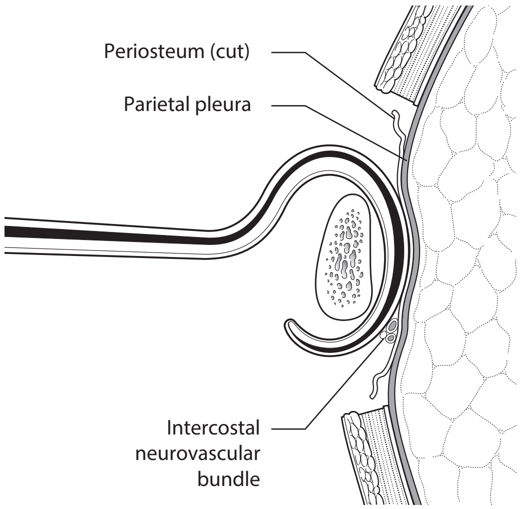


Figure 19.23 A curved instrument (Doyen) is placed carefully around the rib in the subperiosteal plane.

Figure 19.24 Incision marked for iliac bone harvest on the left side. The anterior superior iliac spine (ASIS) is shown. For orientation the groin in superiorly and the umbilicus is under the green marking pen.

Figure 19.25 Dissection through the overlying muscles.

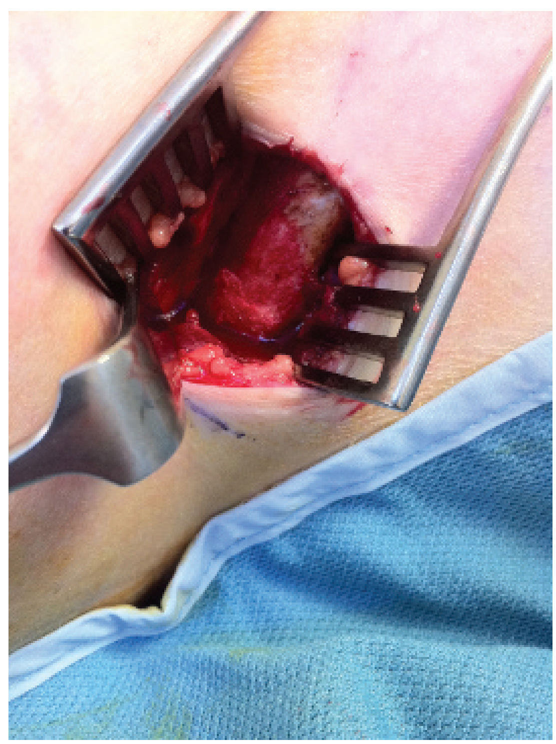


Figure 19.26 Exposure of the iliac crest with muscle and periosteal stripping.

keep draining blood for days. If the periosteum and muscle are tightly approximated, this seems to reduce the haematoma by tamponade action. Bone wax should be avoided as this produces a foreign body reaction often requiring further exploration of the wound. It may be helpful to place the suction drain just subcutaneously to avoid a more superficial haematoma.

Figure 19.27 Bone cuts have been made using saws and and the medial part of the crest can be removed using an osteotome. It is important to protect the medial structures when completing the bone cuts.

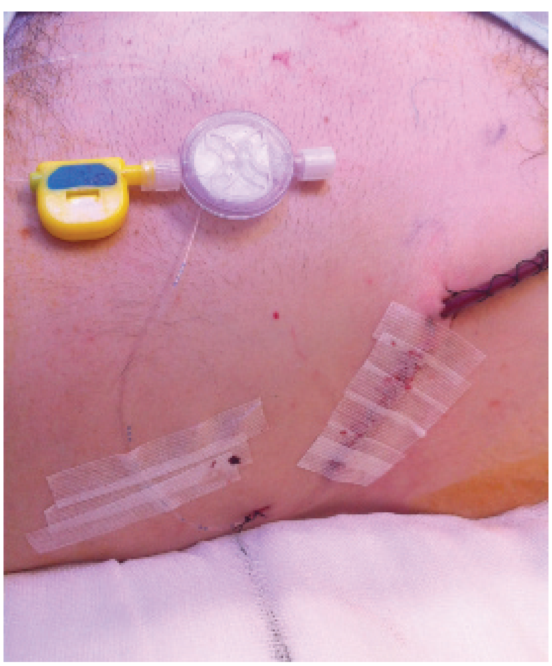


Figure 19.28 Epidural catheter placed in the wound for instillation of regular local anaesthesia to reduce post operative pain.

The process can be made less painful by a trephining technique. A small 1-cm stab incision is made on to the anterior crest and a trephine is directed posteriorly/inferiorly.

This produces a core of cortical cancellous bone and a much smaller volume than an open procedure. It is closed in two layers.

Tibia

This is usually a trephined procedure so that the cores of corticocancellous bone are harvested (see Figure 19.29). The bone is taken from the pyramidal shaped plateau, above the shaft and away from the joint, and in children away from the epiphyseal growth centre (Figure 19.30).

The landmark to make the 5-mm stab incision down to bone is on the medial aspect just above the patella protuberance. The head of the fibula provides a useful guide to the position of the growth centre at the epiphysis, which is above this imaginary horizontal line. Multiple cores are harvested into the pyramidal area. Closure is normally a single layer.

The fibula can on occasion be harvested as a non-vascularized graft, but this is unusual. In the author's experience, a non-vascularized fibula has been successfully used as a free graft when the carotid artery failed to flow during arterial anastomosis. In these instances, it is advisable to remove all soft tissue from the bone. Clearly this would not be suitable when a skin flap was being harvested as well but the fibula itself might be successful as a free bone graft.

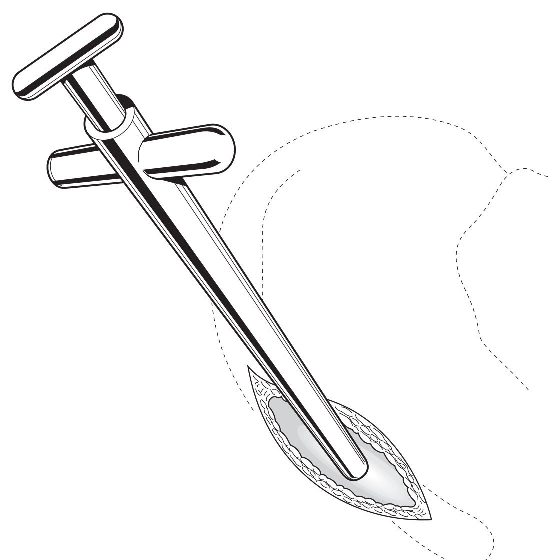


Figure 19.29 The outer sleeve of the trephine stabilizes the trephine on the iliac crest, so a core can be extracted. Normally only a small 'stab' incision is needed.

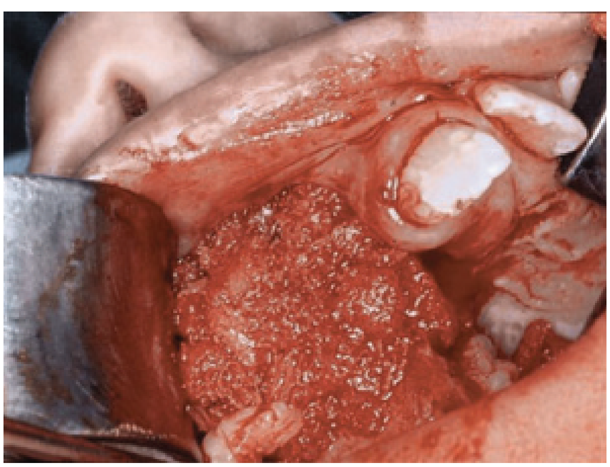
Intra-oral sites

After local anaesthetic injection, wide exposure via a mucoperiosteal flap is performed to identify and preserve important structures (such as the mental nerve). It is advisable to use a suction device with a bone trap to supplement the harvest. If bone is to be removed from the anterior mandible, a small strut of bone is preserved in the midline to maintain the chin contour. Two small box-shaped cuts are made in the cortical plate and lifted free. The bone is then curetted from the marrow, which is usually very vascular. It is not necessary to have any suction drainage, but closure of the mucosa should be in two layers, the deeper sutures should pick up the mentalis muscle and ensure its re-insertion high up the alveolus. An elastic adhesive dressing is then applied in the mental groove further pulling up and supporting the muscle insertion to prevent ptosis. Patients will sometimes have a feeling of numbness to their anterior teeth, which may persist for a considerable time. Posterior lateral harvest from the mandible follows the same principle, removing the lateral cortical plate from behind the last molar to the lateral ramus. Closure has less tension as it is supported by the masseter and a drain is not needed.

As with all intra-bone harvesting, the yield is small and it is necessary to grind up the cortical plate as well as use the bone trapped from the suction.

Vascularized bone grafts are discussed elsewhere.

(a)



(b)

Figure 19.30 (a) 1, Head of fibula, which can be easily palpated, below the epiphysis; 2, epiphysis; 3, the trephine should not enter the shaft; 4 entry site. (b) The tibial graft easily fills this cleft alveolar defect.

CARTILAGE GRAFTS

There are a number of frequently used sites as outlined in Table 19.3.

Surgical Techniques

See Figures 19.31 through 19.33.

Costochondral cartilage

Rib harvesting has been described in the section 'Non-vascularized bone harvesting'.

Ear

There are two sites, the small concave conchal bowl area and the longer curved area between the helix and antihelix. The site is infiltrated with local anaesthetic for pain relief and to aid the dissection. The flap is raised and the clean cartilage surface exposed. Both sites are approached anteriorly, although they can be harvested from behind if prevention of a visible scar is essential. The skin flaps are sutured in one layer and a compression dressing with tie over sutures placed to prevent haematoma formation.

Nasal septum

After infiltration with local anaesthetic, two approaches can be used. Traditionally, a small curved anterior incision is made on one side of the septum. An alternative is to make a high anterior intra-oral incision around the nasal spine. This has the advantage of picking up the septal cartilage low down on the palatal shelf and the stripping of the mucoperiosteum is significantly simpler and easier than the traditional approach. Stripping of the mucoperiosteum is the difficult part of the procedure and a sharp dissector is essential, to ensure no perforations of the mucosa occur. If a

Table 19.3 Frequently used sites for cartilage grafts.

Site	Advantages and disadvantages
Rib	Can be harvested with bone
	Good bulk, but limited length
	May 'grow' in children
	Painful
Ear	Small area, and thin
	Not 'flat'
	Painful
Nasal septum	Invisible scar
	Flat
	Good size, but thin
	Few complications

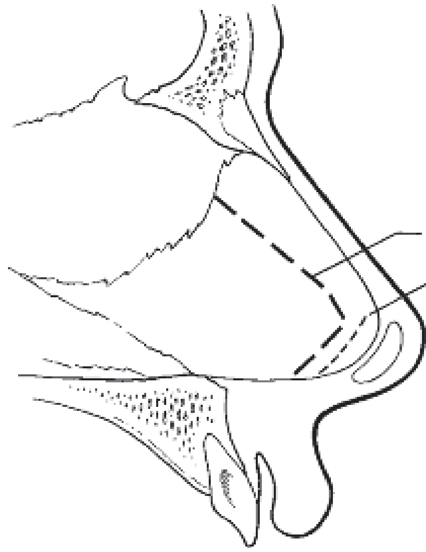


Figure 19.31 Right lateral view of nasal septum to show (a) mucosal cut anteriorly and (b) septal cut a few millimetres posterior to this.

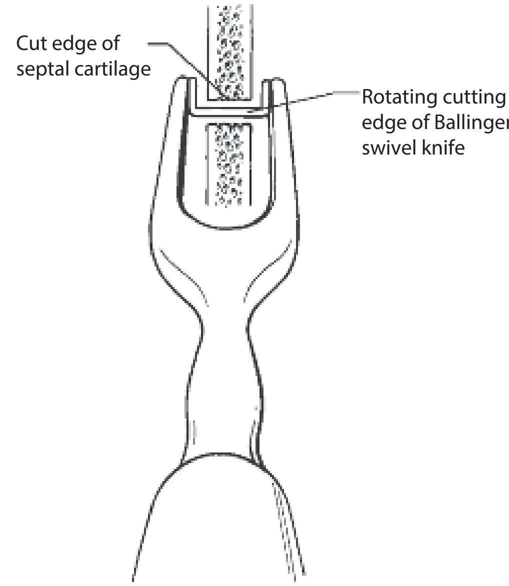


Figure 19.32 Ballinger swivel knife cutting the septal cartilage.

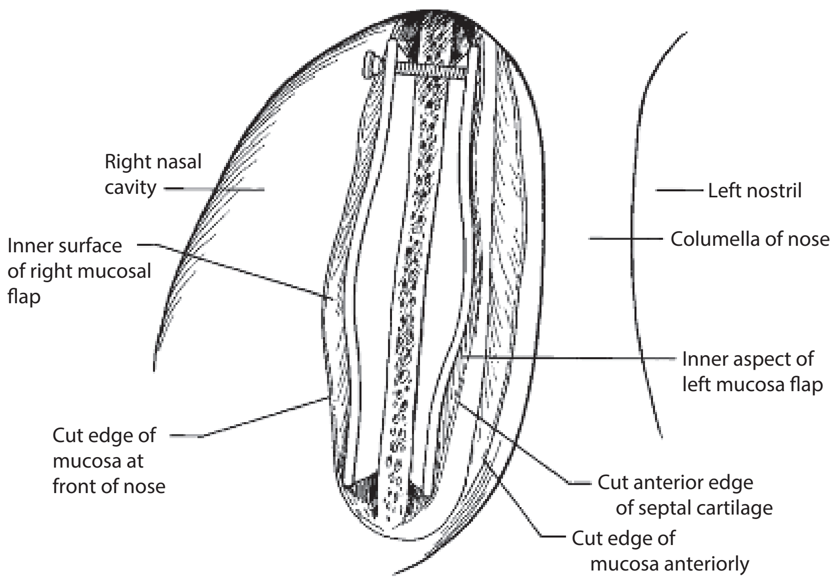


Figure 19.33 View of the cut surface of the septal cartilage from the front through the right nostril after retraction of the mucoperichondrial flaps with a Killian's speculum.

perforation does occur in both surfaces, a permanent fistula is likely to create an irritating whistling sound on breathing. Once the mucoperiosteum has been raised on the operative side, an incision is made through the cartilage and stripping commenced on the contralateral side. The septum can then be excised and harvested. If the nose is not to 'collapse' a horizontal and anterior vertical strut of cartilage about 5 mm in width must be preserved. Closure is in a single layer and supplemented by through and through mattress sutures to prevent haematoma formation. Sometimes, bilateral packs are placed to prevent haematoma formation but, while a traditional approach, its value in producing compression in the right place is doubtful.

Top tips

- When replacing skin in the facial region, the donor skin or skin flap should ideally be from same aesthetic zone.
- Meticulous technique and haemostasis and a two-layer closure is essential for the best results.
- A split-thickness skin graft should be no thicker than 0.2 mm (the thickness of a size no. 15 scalpel).
- There are many sites for harvesting non-vascularized grafts but the iliac crest and costal cartilage provides a good amount of bone and cartilage, respectively, with low morbidity at the donor site.
- A non-vascularized bone only fibula may be successful if when harvested it is not possible to do microvascular reconstruction for whatever reason.

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20

Microvascular surgery – Principles

CYRUS J KERAWALA

CONTENTS

INTRODUCTION

Within the head and neck, microsurgical reconstruction is employed when other options such as local and distant flap transfers are deemed inappropriate. Although microsurgery is widespread it is not the first choice in the reconstructive ladder and may not be the best solution for all defects. It does, however, offer the surgeon the widest range of possibilities for complex reconstruction.

INDICATIONS

These include as follows:

- Replacement of vital structures, e.g. glossectomy defect
- Obliteration of cavities, e.g. maxillectomy defect
- Bone reconstruction, e.g. following segmental mandibular resection
- Replacement of muscle and nerve function, e.g. facial reanimation
- Alimentary tract reconstruction, e.g. after laryngopharyngectomy

CONTRAINDICATIONS

Microsurgical transfers are commonly long and technically demanding operations. In addition, emergency re-intervention may be necessary. Contraindications for this type of procedure therefore include medical illnesses that preclude the ability of a patient to tolerate prolonged anaesthesia. Advanced age is not necessarily a contraindication, nor is a potentially severe medical problem so long as it is well controlled.

PRE-OPERATIVE WORKUP

A comprehensive history and physical examination is mandatory as is close liaison with involved anaesthetic and intensive care staff. Pre-optimization of patients may be advantageous in selected cases. Many patients undergoing microsurgery will have already undergone imaging dependent on their primary disease but additional investigations specific to the reconstruction may also be appropriate, e.g. limb angiography.

SELECTION OF DONOR SITE

Decision-making is critical to the success of microsurgery. The choice of the optimal flap is based on a combination of factors that include the type of tissue required, pedicle length and flap reliability. In addition, consideration should be given to donor-site morbidity.

Within the head and neck, a large number of options exist. The microsurgeon should be familiar with the

majority although inevitably some will be used more than others. There should be avoidance of flap 'favourites' since ultimately each defect should be reconstructed on its merits.

Within the head and neck, most forms of reconstruction can be comfortably undertaken with 10 flaps:

1. Radial forearm free flap (RFFF)
2. Anterolateral thigh flap (ALT)
3. Lateral arm flap
4. Rectus abdominis
5. Latissimus dorsi
6. Fibular
7. Vascularized iliac crest (deep circumflex iliac artery [DCIA])
8. Scapular/parascapular
9. Jejunum
10. Gracilis

In broad terms, the above can be divided into three groups, namely soft tissue flaps, hard tissue flaps and combinations. The choice of soft tissue flap very much depends on the volume of the defect. The body habitus of the patient in part determines bulk although variation in operating technique may overcome this (e.g. intra-operative thinning of ALT). In bony reconstruction, the operating surgeon may have a lesser degree of control (e.g. double-barrelled fibular to confer alveolar height).

MICROSURGICAL PRINCIPLES

Attention to detail is mandatory. Having planned the flap based on the size and type of tissue required an alternative reconstruction should always be considered as a 'lifeboat'. Recipient vessel location should be planned out with potential zones of injury (e.g. previous radiotherapy fields). Two-team operating should be employed wherever possible to both minimize the length of the operation and ensure that a well-rested surgeon is available for the more technically challenging aspects of the operation.

The overall plan should be discussed with the anaesthetist including details of the length of procedure and required positioning of the patient. Potential donor sites should be devoid of vascular access. During the operation and in the immediate post-operative period, prolonged use of vasoconstrictors should be avoided. The patient should be adequately hydrated with a good central venous pressure. Likewise, the patient's core temperature should be maintained to avoid vasospasm. If hypotensive anaesthesia is adopted at any stage (e.g. during ablation) then this should be reversed prior to microsurgery.

The main enemy of the microvascular surgeon is fatigue. Physical exertion, alcohol and caffeine should be avoided for at least 24 hours in individuals prone to a tremor. The operator should take short breaks to minimize waning performance that can accompany long periods of concentration. Above all, both the microsurgeon and assistant should feel physically comfortable throughout with appropriate seating.

Optical systems

- *Magnifying ocular loupes.* Loupes are often more convenient than the microscope for preliminary dissection and can be used for anastomosis of vessels greater than 3 mm in diameter. Simple models with elasticated headbands magnify up to 1.8× whilst more sophisticated binocular loupes fitted to spectacles can provide up to 4× magnification (Figure 20.1). Loupes with higher magnifications tend to have small fields of vision and depth of focus.
- *Operating microscope.* Although the operating microscope has many advantages in providing magnification and illumination, it brings with it additional problems of cost, set-up time and intra-operative positioning. A double-headed operating microscope with the surgeon and assistant at opposite ends is essential for head and neck reconstruction (Figure 20.2). Most commonly this set-up is achieved through the use of beam splitters so that the surgeon and assistant have the same view. Coaxial illumination is also important to avoid shadows. Because of the frequent need for changing magnification zoom systems operated by either a foot or finger should be incorporated. Through-the-microscope photographic or DVD capabilities enhance teaching and documentation.

Instrumentation

Most microsurgical procedures can be performed with a simple, well-maintained basic set of instruments (Figure 20.3).

- *Jeweller's or watchmaker's forceps* (hereafter called microsurgical forceps). The tips of these must meet evenly over a length of at least 2 mm.

Figure 20.1 Binocular loupes.

Figure 20.2 Double-headed operating microscope.

Figure 20.3 Microvascular instruments.

- *Vessel dilators.* These are microsurgical forceps rounded and polished at the tip. Closed tips can be inserted into the end of a divided vessel with minimal trauma.
- *Needle holders.* Purpose-designed models have spring-loaded handles that have a round or flat grip and are curved, angled or straight depending on operator preference.
- *Dissecting scissors.* These should be spring handled. The curved blades can be short or long.
- *Adventitia scissors.* These are identical to dissecting scissors but have straight blades.
- *Vessel clamps* (Figure 20.4). Spring-loaded varieties are available for arteries and veins. Some surgeons also use double-approximater clamps to aid anastomosis.
- *Instrument case.* A metal-lined case with rubber spigots provides insurance against instrument damage.

At least two sets of microvascular instruments should be available in case emergency re-operation is necessary. Whenever instruments are not in immediate use, the tips should be protected with rubber tubing. Regular demagnetization is necessary.

Figure 20.4 Vessel clamps.

BASIC ANASTOMOTIC TECHNIQUE

Essentials for a patent anastomosis

There are several essential requirements to ensure an adequate anastomosis with long-term patency:

- There should be meticulous, atraumatic dissection of involved vessels with ligation or selective coagulation of branches.
- The vessel wall and the intima at the site of the intended anastomosis must be resected to apparently normal tissue. Care should be taken to inspect the lumen of an artery for atherosclerotic plaques or vein for adjacent valves.
- Adequate blood flow should be demonstrated from the recipient artery prior to anastomosis. If flow is impaired, dilation can be attempted or pharmacological agents can be applied (e.g. papaverin).
- Anastomoses should be completed without tension, employing vessel immobilization or vein grafts as necessary.
- Overhanging adventitia should be removed and sutures placed without trauma to the intima. All traces of contaminants should be irrigated with heparinized solutions (100 U/mL) prior to completion of the anastomosis.

End-to-end anastomosis techniques

Personal preference means that some surgeons use interrupted sutures and some prefer a continuous pattern. The technique most commonly taught is the

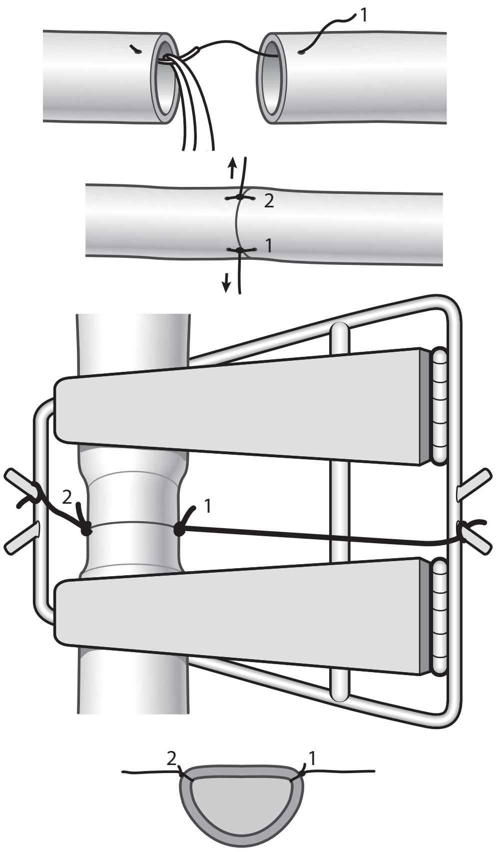

Figure 20.5 Triangulation method of vessel approximation.

joining of vessels end-to-end using a triangulation method whereby two stay sutures are inserted 120° apart so that when they are placed under tension the front wall of the anastomosis is stretched laterally (Figure 20.5). As a result, the back wall tends to fall away and is less likely to be picked up inadvertently. In the clinical situation, this is not always possible and many prefer two sutures at 180°.

After vessels have been prepared, the two stay sutures should be placed and the ends left long, such that they can be anchored to the cleats of a double clamp or held by an assistant. The front wall is then sutured using square or reef knots that must lie flat against the anasto-mosis line so that the threads do not project into the vessel lumen (Figure 20.6). Two or more co-optation sutures are then placed between the stay sutures before the vessel is rotated through 180°. The anastomosis should be critically appraised before the back wall is closed (Figure 20.7).

The venous anastomoses is performed in an identical manner to the artery but can be technically more demanding because the absence of a substantial muscularis means the vein wall collapses easily. Minimal adventitial stripping is therefore recommended. Overuse of irrigation should also be avoided since it tends to strip the adventitia.

Once the anastomosis is complete, the necessary clamps are released and blood flow observed under magnification.

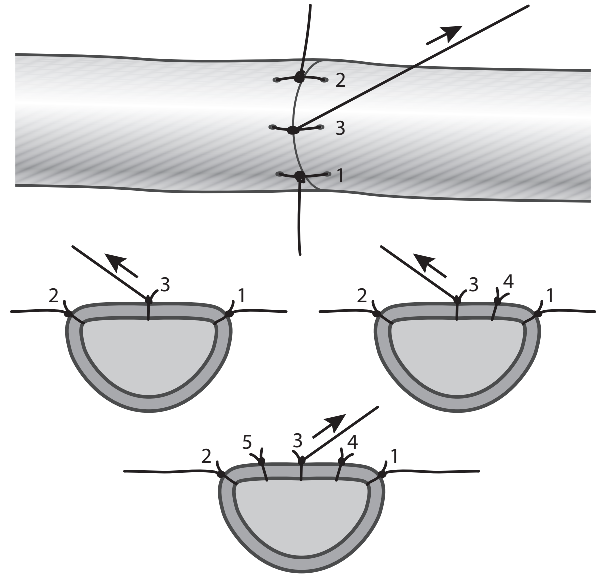

Figure 20.6 Completion of front wall co-optation.

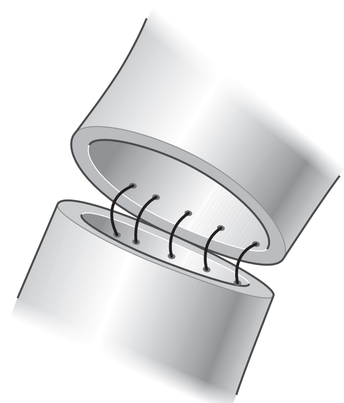

Figure 20.7 Critically appraise rotated vessel before back wall closure.

An initial small ooze commonly occurs but generally stops within a few minutes. Pulsatile bleeding requires placement of further sutures.

End-to-side anastomosis technique

The arteriotomy or venotomy in the recipient vessel is the most critical step in this procedure since it must match the size of the vessel to be anastomosed. The adventitia around the intended site should be carefully removed so that it does not protrude into the newly formed lumen. Stay sutures are initially placed at the proximal and distal ends of the arteriotomy or venotomy (Figure 20.8). Secondary co-optation sutures are then inserted along the anastomosis line with either the front or back wall being closed first depending on operator preference (Figure 20.9).

Size discrepancy

Discrepancy in vessel size can be solved by performing an end-to-side anastomosis. Alternatively the smaller vessel can be dilated, transecting on a 45° diagonal (Figure 20.10) or incised to create a fishtail (Figure 20.11).

Assessment of suture lines

A critical assessment should be made prior to accepting the anastomosis. The most common errors in technique include as follows:

- Stitches are too tight
- Stitches are too loose so that a loop of material intrudes into the lumen
- Too many or too few sutures
- Suture holes are not equidistant from the edge
- Uneven spacing between sutures
- Inversion or eversion of tissue edges

Microsurgical couplers

Some surgeons prefer the use of microvascular anastomotic couplers to hand-sewn anastomosis. The coupler is a mechanical implantable device comprising an interlocking ring-pin design. Its use is most established in the end-to-end anastomosis of veins.

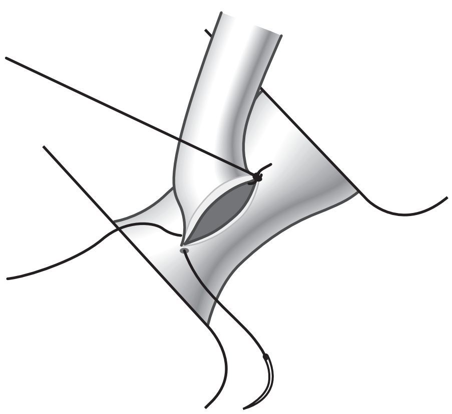

Figure 20.8 Stay sutures in end-to-side anastomosis.

Patency test

Anastomotic patency can be assessed in a variety of ways. Arterial patency is indicated by well-dilated vessels demonstrating either pulsatile elongation or expansile pulsation. The empty and refilled patency test ('milking' an anastomosis) is traumatic and should be performed as gently and infrequently as possible. Ultimately, anastomotic

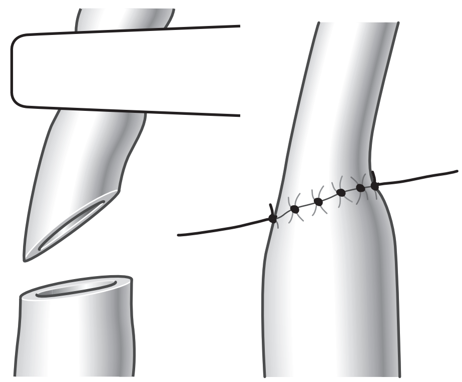

Figure 20.10 Diagonal transaction of vessel.

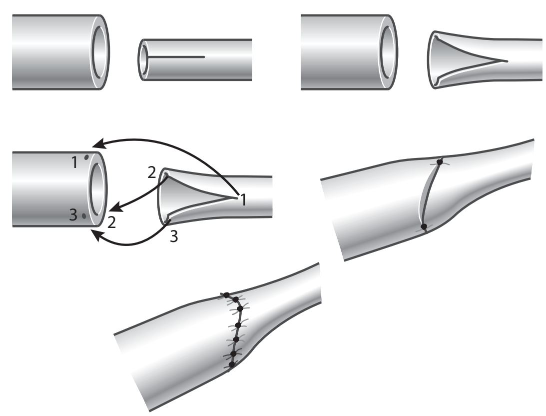

Figure 20.11 Fishtail technique.

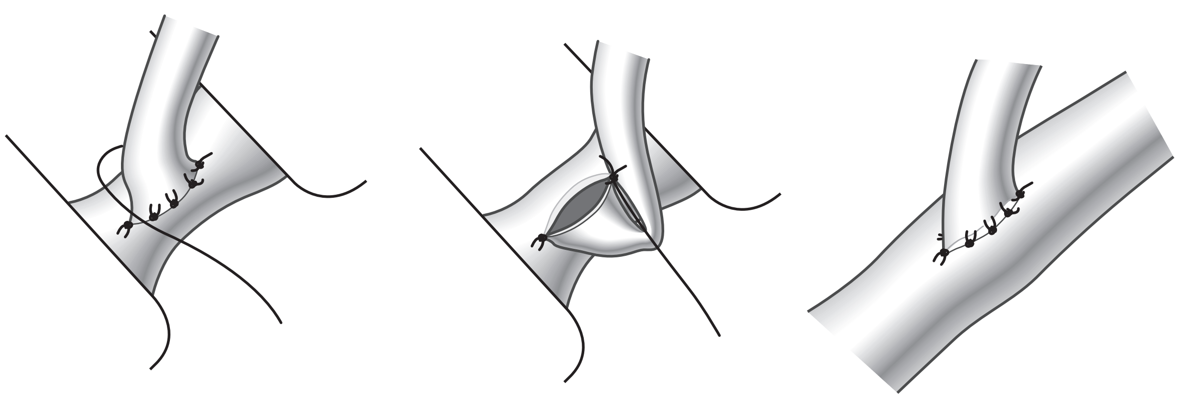

Figure 20.9 Completion of end-to-side anastomosis.

patency can be assessed by a return of colour and capillary refill to the revascularized tissue.

POST-OPERATIVE CARE

Post-operative staff must be familiar with free-flap monitoring and the general care of the microsurgery patient. A hyperdynamic circulation with adequate hydration, filling pressures, urine output and body temperature should be the aim. Pain should be controlled to prevent anxiety that in turn leads to vasoconstriction. Anti-coagulation may be used depending on the surgeon's preference (e.g. Dextran 40, heparin, aspirin).

Free-flap monitoring is also dependent on preference. The criterion standard remains careful and regular clinical examination of the flap (colour, skin turgor, refill etc.). Some surgeons prefer a needle test which should result in the oozing of bright red blood up to a minute after the needle is withdrawn. Other monitoring techniques include as follows:

- Surface/implantable Doppler ultrasound
- Temperature monitoring
- Pulse oximetry
- Intra-venous fluorescein
- Near infrared spectroscopy
- Laser Doppler flowmetry
- Microdialysis

If vascular compromise is suspected within a free flap, immediate measures should be taken as follows:

- General assessment of the patient (e.g. exclusion of hypotension)
- Repositioning of the patient to relieve possible pedicle compromise
- Exclusion of haematoma
- In the absence of haematoma release of the vacuum on any relevant drain in case the pedicle is in contact with the drain holes
- Removal of compressive dressings or tight sutures

If such simple manoeuvres are not successful, immediate re-exploration is critical so long as the patient's general condition allows it.

COMPLICATIONS

Microsurgical operations are by their very nature physiologically traumatic for the patient. Potential major complications may occur including myocardial infarction, stroke and death. Informed consent is mandatory and should include detailed discussions with appropriate warnings to include as follows:

- Intra- and post-operative bleeding, with possible transfusion
- Donor and recipient site infection
- Morbidity specific to the free flap used
- The need for emergency re-operation
- Partial or total flap loss
- Possible revisionary operations (e.g. flap thinning)

RECIPIENT VESSEL SELECTION

The delivery of blood into and out of the flap depends on meticulous harvesting of the nutrient pedicle, careful preparation of the recipient vasculature and a technically perfect anastomosis. Care must also be paid to the geometry of the pedicle to prevent tension and kinking caused by head mobility.

General considerations

Recipient vessel selection is one of the most critical steps in ensuring a successful outcome. Careful intra-operative selection greatly facilitates the process of revascularization and as a result vessels should be selected and isolated prior to flap division to minimize the ischaemic period. The majority of the flap insetting should be completed prior to the anastomosis since this is not only facilitated by working on an ischemic flap but the position of the donor vessels becomes fixed after insetting which allows tension on the vascular pedicle to be predicted.

Aside availability, a number of other factors must be considered when selecting recipient vessels. The choice of vessel is in part limited by the site of the defect and particular flap employed (e.g. in the DCIA, the venae commitantes can be unsuitable for anastomosis until they join to produce a vein of suitable calibre). The presence of a previous ipsilateral radical neck dissection may limit the availability of recipient vessels. Advanced age and previous irradiation may also lead to athrosclerosis.

Recipient artery selection

The two major sources of arteries are branches of the external carotid artery and the thyrocervical trunk. Because of their proximity to defects, the upper branches of the former are the most commonly employed. However, the thyrocervical trunk and in particular its transverse cervical artery (TCA) are almost always preserved following neck dissections and provide a useful alternative. The TCA can be traced for a significant distance underneath the trapezius muscle and comfortably transposed into the mid portion of the neck. This vessel is far less prone to athrosclerosis than the external carotid artery and usually lies outside the area of most intense radiation therapy. Rarely, the internal mammary system can be used.

Recipient vein selection

There are three primary recipient veins in the neck. Whilst the internal jugular vein or its immediate branches serve as an excellent outflow, the external jugular and transverse cervical veins are alternatives. The anterior jugular vein

should be avoided since its caudal portion is at risk during tracheostomy. The cephalic vein may be used as a source of vein grafts or can be used as a recipient vein if traced distally into the arm and then transposed over the clavicle. Rarely, a Corlett loop can be fashioned from a vein graft to produce a temporary arteriovenous fistula.

Top tips

- For the novice microvascular surgeon repeated in vitro practice is essential.
- The microsurgeon should be well rested prior to the operation and comfortable throughout it.
- Flaps used should reflect anatomical and functional considerations rather than the surgeon's favourite.
- The surgeon should be critical about every suture placed. If he or she is not satisfied that suture should be replaced.
- The surgeon should be critical about the completed anastomosis. It is far better to repeat an anastomosis during the time of primary surgery than return to it once vascular compromise is apparent hours later.
- Recipient artery and vein selection is imperative with vessels being chosen outside any potentially compromised field.

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21

Radial forearm flap

CHRISTOPHER M AVERY

CONTENTS

PRINCIPLES AND JUSTIFICATION

The radial forearm flap may be harvested as a fasciocutaneous, septocutaneous, fascial or osteocutaneous flap. A sensory nerve or the palmaris longus tendon may also be included. The soft tissue flap is an accepted 'workhorse' for oral reconstruction, providing a large area of relatively hairless and thin pliable skin. The flap is straightforward to raise and has a long vascular pedicle.

Management of morbidity at the donor site has focussed on the cosmetic defect and the relatively high incidence (typically over 10%) of skin-graft loss, delayed healing and tendon exposure. The incidence of these complications can usually be reduced to below 5% by elevation of the flap in a suprafascial plane. In addition, over 70% of the strength of the original radius is lost after the harvest of an osteocutaneous flap and the mean incidence of fracture is 25%. A fracture results in further significant morbidity and often requires secondary surgery. This complication and the relative lack of bone volume resulted in the radial osteocutaneous flap being superseded by alternative options. However, the use of prophylactic internal fixation, with a bone plate, has now become well established and has reduced the incidence of fracture to approximately 2%.

INDICATIONS

- Reconstructing mobile areas of the oral cavity and oropharynx.
- Not an ideal cosmetic replacement for facial skin but useful for reconstruction of lip and circumoral defects when the palmaris longus tendon improves lip competence.
- Indications for the osteocutaneous flap have declined as other donor sites offer greater volume of medullary bone or better quality cortical bone.
- It retains a 'niche' role for small volume bone defects of the anterior or partial maxillary alveolus, central palate, nasal bone and orbital rim. It may still be useful for the thin edentulous mandible, particularly if associated with a significant soft tissue defect and/or implant placement is unlikely.
- When the general medical or vascular status precludes the use of alternative flaps.
- The role of sensate flaps remains controversial with no proven functional or quality of life benefit.
- Fascia-only flaps are less dimensionally stable and heal by secondary 'mucosalization'. They can be used for small palatal defects or over areas of exposed bone.
- A fascial flap may be pre-laminated with skin or a mucosal graft as a delayed procedure for elective reconstruction.

SURGICAL ANATOMY

In the distal forearm, the radial artery lies in the superficial subcutaneous tissues between the brachioradialis and flexor carpi radialis tendons. It is enveloped by the conjoining of two layers of deep fascia (Figure 21.1) and gives off multiple small vessels (septocutaneous perforators) to the overlying skin from a subdermal plexus. Musculoperiosteal perforators pass inferiorly to the musculature and periosteum of the radius through the flexor pollicus longus (Figure 21.2). Drainage of the flap

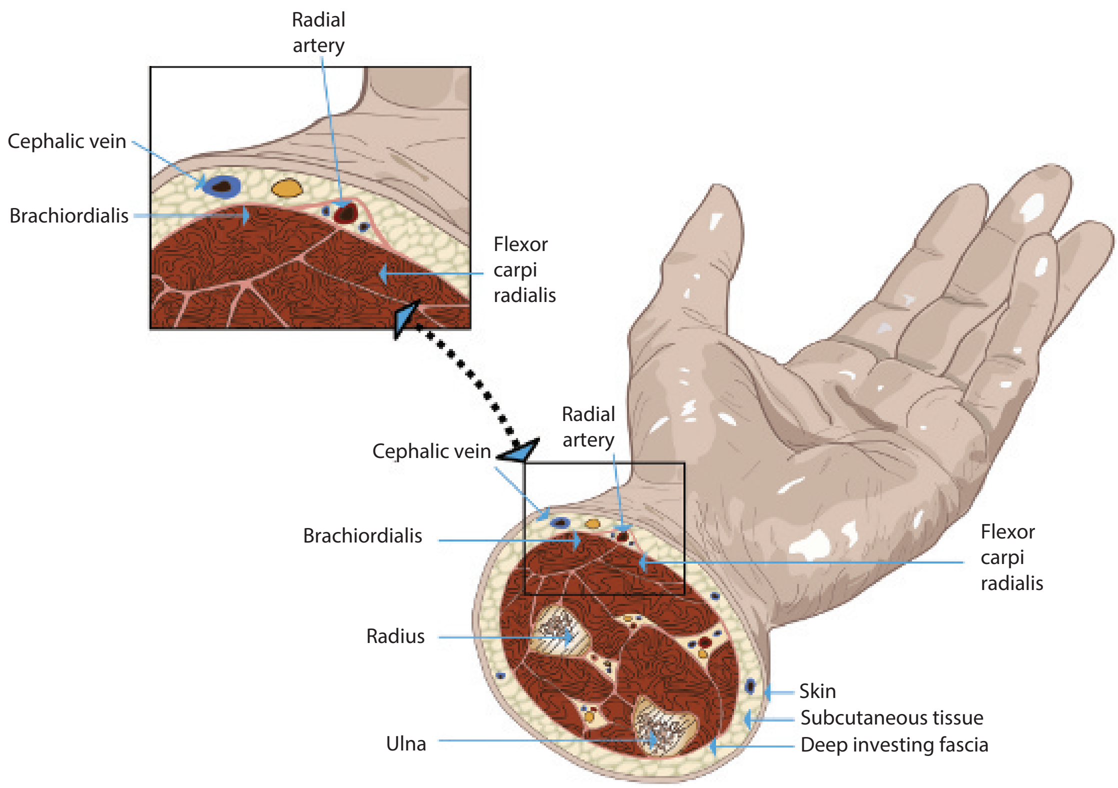

Figure 21.1 Cross section of wrist with radial artery enveloped by deep fascia.

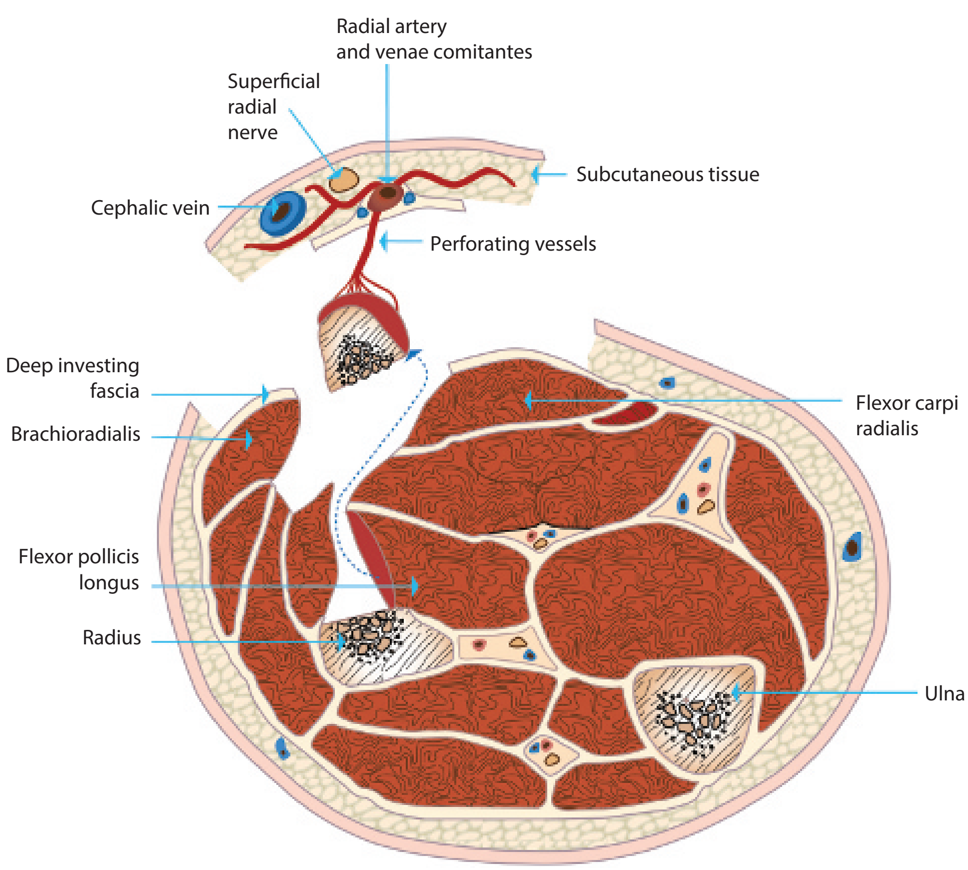

Figure 21.2 Cross section of osteocutaneous radial flap.

is via the radial venae comitantes and/or the superficial subcutaneous veins, often the cephalic vein. A single vena comitans often provides satisfactory venous drainage but a double anastomosis or confluent vein may be preferred.

Although conventionally raised as a fasciocutaneous flap the deep fascia is not essential for skin perfusion. The enveloping fascia around the pedicle may be opened and a septocutaneous flap elevated in the suprafascial plane (Figure 21.3). If the fascial covering of the flexor tendons is retained the problems associated with skin graft healing may be minimized when compared with the subfascial donor defect.

A branch of the lateral or medial cutaneous nerve of the forearm is incorporated if a sensate flap is required.

PRE-OPERATIVE

The non-dominant forearm is preferred (Figure 21.4). The sufficiency of the residual ulnar supply to the hand is confirmed clinically by the Allen test and supplemented by Doppler studies. The entire skin of the forearm may be safely transferred but most intra-oral defects are reconstructed with flaps of 7 cm × 5 cm or smaller. The flap is designed with the artery towards the lateral aspect to avoid the more hirsute skin and an unsightly extension over the radial aspect of the forearm. If the distal forearm skin is especially thin then the flap may be positioned more proximally. Most defects are repaired with a full- or partial-thickness skin graft but small defects may be closed directly with an ulnar transposition flap or a V- to Y-closure, although these latter techniques may cause additional oedema and numbness.

OPERATION

Fasciocutaneous radial flap

Incision

The flap is raised under tourniquet control (200-mmHg pressure) following partial exsanguination by elevation. Binocular loupes are useful to identify small feeding vessels that should be carefully managed with bipolar diathermy or preferably ligation clips. Starting at the medial (ulnar) border the incision is deepened through subcutaneous fat and fascia to expose the underlying muscle. The incision is extended around the proximal and distal aspects. The assistant applies gentle traction to facilitate sharp dissection beneath the fascia from medial to lateral. Remaining in the subfascial plane but taking care to avoid damaging the paratenon as the palmaris longus and medial edge of the flexor carpi radialis are exposed (Figure 21.5).

Identification of the pedicle

As the lateral (radial) border of flexor carpi radialis is approached, continue in the subfascial plane and identify flexor pollicis longus lying at a deeper level. This avoids inadvertent detachment of the vascular pedicle now seen on the undersurface of the flap. The distal radial artery

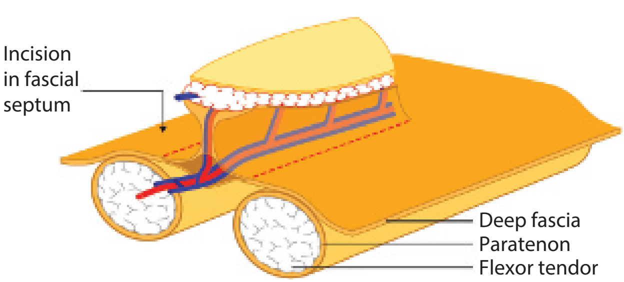

Figure 21.3 Incision of investing fascia to elevate septocutaneous radial flap.

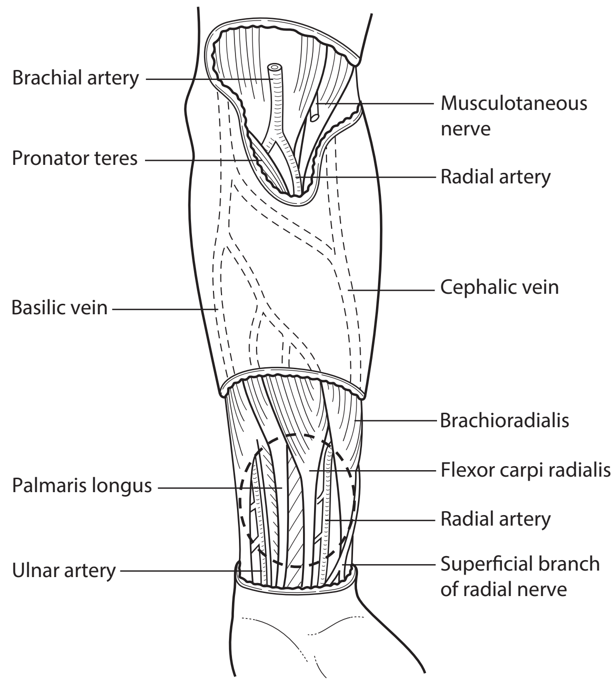

Figure 21.4 Superficial anatomy of forearm.

Figure 21.5 Ulnar elevation of fasciocutaneous flap in subfascial plane.

should be divided and ligated to confirm the position of the pedicle (Figure 21.6).

Flap mobilization

The circumferential incision is completed on the lateral (ulnar) aspect ensuring that the pedicle lies within the margins of the flap. The superficial cephalic vein, or a main branch to it, may also be included. The brachioradialis tendon is exposed and retracted laterally to identify and protect the superficial sensory branch of the radial nerve. The skin paddle is now elevated taking care to ligate any small vessels passing to the underlying muscle and bone. Flap elevation is facilitated by opening the proximal forearm incision at an early stage. Proximal and lateral subcutaneous dissection is necessary if the cephalic vein or lateral cutaneous nerve is included.

Completion of elevation

The proximal forearm incision is often completed with a z-plasty incision in the cubital fossa. The fascial septum between brachioradialis and flexor carpi radialis is opened to expose the arterial pedicle. The skin flap is held in a damp swab and gently lifted. Small muscular side branches are carefully ligated. A variable amount of subcutaneous tissue may be harvested with the pedicle. The limit of the arterial pedicle is the bifurcation of the brachial artery but full length is rarely needed and the radial recurrent artery, just distal to the bifurcation, can often be spared. The deep and superficial venous systems usually unite at the cubital fossa and the confluent vein will provide additional length (Figure 21.7).

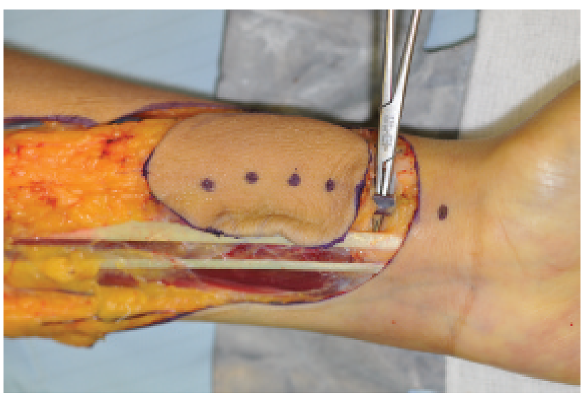

Figure 21.6 Ligation of distal radial artery.

Figure 21.7 Elevation of vascular pedicle with confluent deep and superficial venous systems.

Detachment of the flap and donor-site closure

The tourniquet is released and perfusion of the flap and hand is checked. Complete hemostasis is obtained along the pedicle and on the undersurface of the flap. Allow time for relaxation of small vessel spasm and apply topical papaverine. Closure of the distal forearm incision may be performed at this stage. The flexor tendons may be oversewn with muscle or left exposed (Figure 21.8). The author prefers to repair the donor defect with a full-thickness skin graft from the inner upper arm or inguinal crease and a partial-thickness graft from the outer upper arm or thigh is used for large defects. The veins may be divided first to assess the venous outflow before clamping and dividing the arterial pedicle. A suction drain is inserted and the proximal forearm wound closed. The wrist may be splinted to minimize movement of the tendons. Alternatively, a negative pressure wound dressing is applied without a deep suction drain or splint. The negative pressure dressing holds the skin graft in close proximity to the donor site and the wrist remains mobile (Figure 21.9). The perfusion of both the flap and hand should be closely monitored.

Septocutaneous radial flap

Plane of the suprafascial dissection

Incise the skin to expose the deep fascia. Sharp dissection is carried out in the immediate suprafascial plane. The technique is slightly more demanding and binocular loupes are essential. Flap elevation begins at the ulnar (medial) border as usual and progresses laterally over flexor carpi radialis, stopping short of the radial artery

Figure 21.8 Subfascial donor site.

Figure 21.9 Negative pressure wound dressing.

Figure 21.10 Dissection of septocutaneous flap in suprafascial plane.

(Figure 21.10). A few small fasciocutaneous perforating vessels to the inferior surface of the flap are cauterized.

Dissection along the distal pedicle

The distal end of the arterial pedicle is ligated and divided. Lifting the pedicle exposes the floor of the fascial envelope between the flexor tendons (Figure 21.11). The medial and lateral aspects of this envelope are incised parallel and close to the pedicle. The floor of the fascial envelope becomes progressively thinner and larger musculoperiosteal perforating vessels from the inferior surface of the pedicle are ligated. Dissection on the radial aspect is in the plane of the superficial radial nerve, taking care not to disrupt the subcutaneous plexus. The forearm skin and fascia overlying the brachioradialis and flexor carpi radialis are incised to retract these muscles and the proximal dissection of the pedicle is completed as described in the section 'Flap mobilization'. The donor site remains largely covered with investing deep fascia and often some deep subcutaneous tissue on the radial aspect (Figure 21.12). The author prefers to manage the defect with a fenestrated full-thickness skin graft and a negative pressure wound dressing.

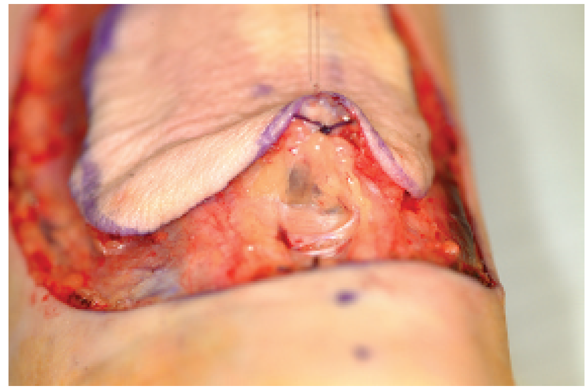

Figure 21.11 Elevation of radial artery within fascial tunnel.

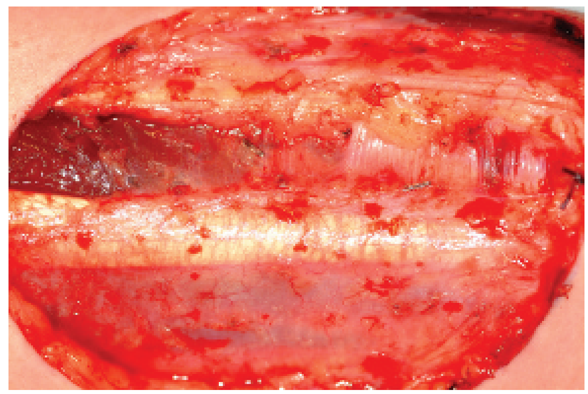

Figure 21.12 Suprafascial donor site.

Composite osteocutaneous flap

Surface markings

The skin paddle and bone graft are marked out. Typically, a maximum of 11–13 cm can be harvested. The limiting factor is the attachment of pronator teres, although this may be reattached if stripped. If prophylactic internal fixation is to be applied allow at least 2 cm from the distal osteotomy to the radial styloid to place a straight bone plate (Figure 21.13).

Skin flap elevation

Dissection of the skin flap is easiest in the subfascial plane but an incomplete suprafascial approach is an option. Starting on the ulnar aspect proceed as far as the lateral (radial) border of the flexor carpi radialis. The distal pedicle is ligated and divided. If the initial dissection is in the suprafascial plane, the fascia must be incised along the lateral border of the flexor carpi radialis.

Preservation of a muscle cuff

The proximal investing fascia is divided to retract the flexor carpi radialis. Damage to the median nerve which lies medial to the distal aspect of the tendon is to be avoided. Retraction exposes the flexor pollicis longus and pronator quadrates, which are incised along the length of the

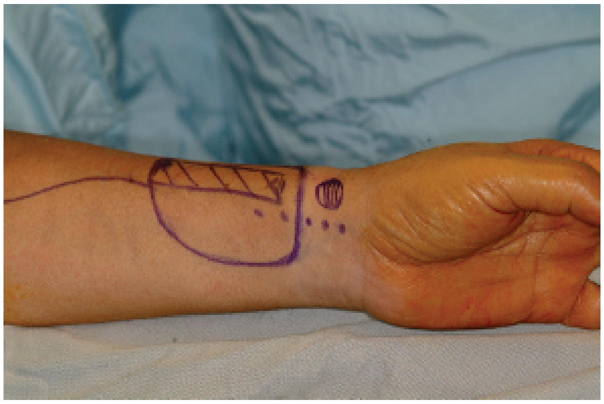

Figure 21.13 Surface markings of osteocutaneous flap.

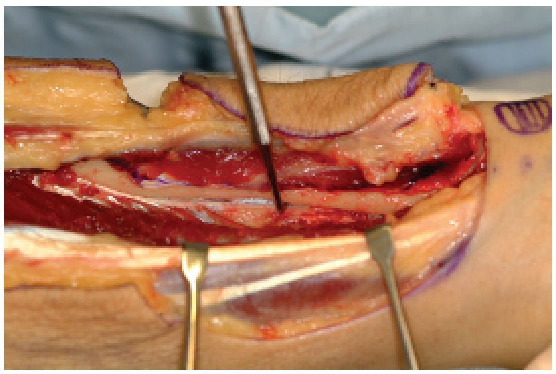

Figure 21.14 Retraction of flexor carpi radialis and identification of lower (posterior) border of radius.

bone graft to reach the ulnar (anteromedial) aspect of the radius. Preserve sufficient muscle cuff to protect periosteal perforating vessels passing through the muscles from the inferior surface of the pedicle. Most perforators run close to or in the lateral intermuscular septum which remains attached to the lateral aspect of the bone graft.

Bone exposure and osteotomy planning

The periosteum is incised and the cuff of flexor pollicis longus sparingly elevated to mark out the osteotomy site. Identify the interosseous and lower (posterior) border of the radius to avoid excessive bone removal, particularly in the mid-section where it curves upward in a convex manner (Figure 21.14). Plan to remove one-third to one-half of the radial circumference of the bone. A computer-generated osteotomy planning template may be utilized.

Osteotomy technique

The horizontal anteromedial osteotomy is performed from the ulnar aspect with either a narrow fissure burr using the 'postage stamp' method or a fine saw. Usually 6–12 cm of bone is required. Take care to protect the cuff of flexor pollicis longus (Figure 21.15). The end osteotomies are

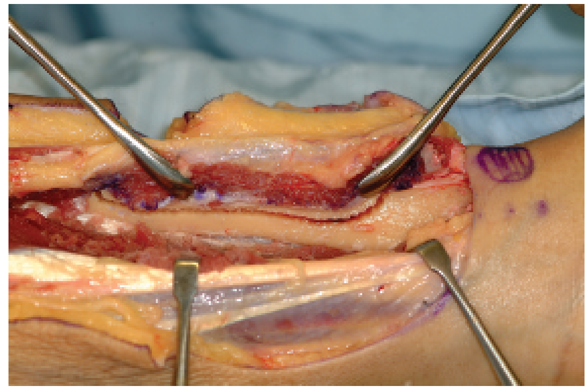

Figure 21.15 Preserve cuff of flexor pollicus longus and osteotomy of radius.

bevelled and may be rounded out with a stop hole to avoid over-cutting and stress concentration. The graft is gently mobilized with a fine-curved osteotome.

Dissection on the radial aspect

Retract the brachioradialis and dissect on the deep surface down to the osteotomy site, taking care to preserve the attachment of the intermuscular septum to the lateral aspect of the bone. The distal aspect of the flap is lifted superiorly by incising the periosteum and dividing any other retaining soft tissues, taking care to avoid damaging the pedicle. The proximal dissection is completed as normal. If proximal muscle attachments have been stripped, these may be reattached.

Bone plating the radius

An anterior or posterior approach may be utilized but the former is probably the most common. The distal osteotomy must be at least 2 cm proximal to the radial styloid to allow space for two screws and to avoid the wrist joint. The proximal and distal muscle attachments are stripped and repositioned later. A 3.5-mm straight dynamic compression plate is adapted to bridge the defect on the anteromedial surface of the radius. At least two bicortical screws are inserted at each end in a neutral (non-compressive) position ensuring both medial and lateral cortices are engaged (Figure 21.16). A weaker but more malleable 3.5-mm pelvic reconstruction plate may be placed over longer defects. More recently, anatomically contoured low-profile 3.5-mm radial plates with unilocking screw systems have been shown to be as effective and a T-shaped plate is helpful if distal space is limited (Figure 21.17).

Donor site management

The flexor pollicis longus and brachioradialis muscles are approximated to cover the plate (Figure 21.18) then the donor site is managed with a skin graft and negative

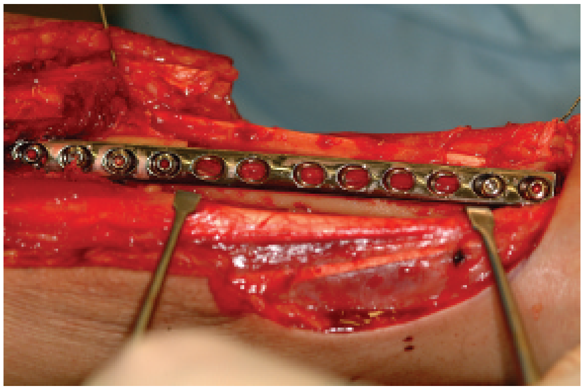

Figure 21.16 Prophylactic internal fixation with a 3.5-mm steel dynamic compression plate.

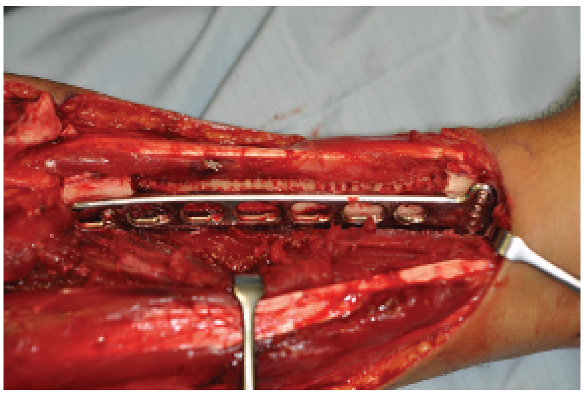

Figure 21.17 Anatomically contoured T-shaped titanium plate.

Figure 21.18 Oversewing of musculature before skin grafting.

pressure wound dressing. A complete above-elbow cast, which may be pre-fabricated, is applied and the arm supported in a sling. A below-elbow cast is placed for 6 weeks when the skin graft is inspected after 10 days. The plate rarely requires removal.

Top tips

- Plan flap with artery at the lateral edge. This avoids hair remaining on the flap and improves aesthetics.
- Using the deep venous drainage system (venae comitantes) simplifies the dissection.
- Let the flap rest at the donor site after elevation. This allows vascular spasm to relax.
- The suprafascial dissection technique significantly reduces donor site morbidity.
- Meticulous haemostasis is essential.
- With a composite flap never harvest more than 50% of the circumference of the radius.
- Prophylactic plating significantly reduces the risk of radius fracture.

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22

Scapula and parascapular flaps

PHIL PIRGOUSIS and RUI FERNANDES

CONTENTS

HISTORY

The subscapular-based system of flaps has enjoyed much popularity in head and neck reconstruction since 1978 when Saijo provided the potential of raising a musculocutaneous flap from the back based on the circumflex scapula vessels.

Subsequently, Gilbert and Teot in 1979 were the first to report the use of such a flap, but it was dos Santos in 1980 who extensively described the vascular anatomy of this donor site.

In 1982, Nassif further elaborated on the vascular territory of the subscapular system and published his variation of the subscapular flap.

In 1981, Teot described the vascular anatomy to the lateral border of the scapula.

Swartz et al. in 1986 and Baker and Sullivan in 1988 are credited with the popularization of this composite osteocutaneous flap for use in head and neck reconstruction.

Furthermore, since 1991 various authors have published extensively on use of the scapula tip as a bone only flap based on the angular branch of the thoracodorsal artery which significantly increases pedicle length.

INDICATIONS

- Segmental resection of the mandible with or without soft-tissue skin paddle
- Anterior mandibular resections involving tongue and floor of mouth
- Extensive defects of the retromolar trigone, glossotonsillar sulcus and oropharynx where segmental mandibular resection is necessary
- Lateral mandible defects with through and through soft-tissue component
- Frail osteoporotic patients
- Patients with pre-existing gait disturbance
- Palatomaxillary and midface reconstruction using scapula tip from the thoracodorsal system
- Vasculopathic patients with compromised vascularity to the foot secondary to atherosclerotic disease

SURGICAL ANATOMY

The subscapular system of flaps arises from the subscapular artery and vein which are branches of the third part of the axillary artery and vein, respectively. The circumflex

scapula artery (CSA) and vein (CSV) together with the thoracodorsal artery and vein form the two primary branches of the circumflex scapular vessels.

The CSA exits through the muscular triangle formed by the teres minor and major muscles and the long head of triceps brachii muscle. It divides further into bony and cutaneous branches in a predictable fashion to supply the lateral scapula border and skin overlying the scapula.

The lateral scapula border is supplied by periosteal branches arising from the CSA whilst the remaining terminal cutaneous branches form the transverse and descending branches supplying the scapula and parascapula skin paddles, respectively.

The CSA is usually accompanied by two venae comitantes which frequently drain into the thoracodorsal vein but in 10% of cases have been shown to drain directly into the axillary vein. The CSV averages 3 mm in diameter. At its origin from the subscapular artery, the CSA averages 4 mm in diameter, whilst at its origin from the axillary artery the diameter increases to 6 mm.

Vascular pedicle length is dependent on the extent of proximal dissection with a pedicle length measuring up to 6 cm available when harvesting the CSA at its origin from the subscapular artery. However, increased pedicle lengths measuring 11–14 cm are possible when the subscapular vessels are divided at their origin from the axillary artery and vein.

The scapula tip is supplied by the angular branch of the thoracodorsal artery, a highly consistent anatomical finding. It branches from the thoracodorsal artery just proximal to a branch supplying serratus anterior or less commonly at a point distal to this vessel and supplies muscular branches to the subscapularis muscle before terminally arborizing in the periosteum of the scapula tip approximately 3 cm from its most caudal point. This vessel is consistently located in the plane between teres major and latissimus dorsi and once identified can be traced to its termination at the scapula tip following transection of teres major.

Sensory supply to the overlying skin is derived from the dorsal rami of the corresponding spinal nerves; however, these nerves have not been shown to maintain useful sensation to skin paddles from this donor site.

Several publications investigating the vascular anatomy of this region have confirmed its predictability and anatomical consistency.

FLAP HARVESTING

Patient positioning

Harvesting of the osteocutaneous scapula flap begins with patient positioning. Traditionally, intra-operative repositioning of the patient, at least once into the lateral decubitus position was necessary following tumour ablation. This unfortunately adds significant operative time as a two-team approach is not possible and sterile preparation and re-draping of the donor site is required. However, intra-operative repositioning can be avoided by placing the patient in a semi-lateral decubitus position exposing the ipsilateral scapula and supporting the patient with an inflatable sand bag. The ipsilateral arm is covered to the elbow with a sterile stocking and the entire upper extremity and posterior trunk can be sterilized and draped in continuity with the head and neck allowing access for the ablative component and harvesting of the scapula flap without violating sterility.

FLAP OUTLINE

In this lateral position, the assistant can support the arm exposing the scapula and axilla. Appropriate skin markings are made including an outline of the scapula and its spine together with the attaching musculature and triangular space. A sterile handheld pencil Doppler is used to trace out the path of the transverse and descending cutaneous branches of the CSA including the CSA itself as it emerges from the triangular space. The CSA and its branches are then outlined on the skin and an appropriate-sized skin paddle is delineated over the respective cutaneous branch. Typically, for the osteocutaneous scapula flap the transverse branch is utilized affording greater flexibility of the skin paddle relative to the bone, whilst the parascapular flap is based on the descending cutaneous branch.

HARVESTING

Harvesting begins by elevation of the skin paddle from medial to lateral in a suprafascial plane relative to infraspinatus and continued until the lateral border of the scapula is reached. In this plane, one can often see the transverse branch and follow it to its confluence with the descending branch and the parent circumflex scapula vessels more proximally as dissection is carried towards the triangular space. Once these vessels are confirmed, the teres major is exposed to its inferior border and transected followed by division through infraspinatus with bovie down to scapula periosteum. This allows exposure of the lateral scapula border and the required length of bone can be outlined.

An oscillating saw is then used to complete the bony cuts with a malleable retractor placed on the deep surface of the scapula whilst making the superior and inferior lateral cuts to protect the underlying chest wall. Upon completion of the bone cuts, the bone segment can be retracted out of the wound to expose the underlying subscapularis and bipolar cautery is used to divide subscapularis leaving a small muscle cuff on the undersurface of the bone thus preserving the muscular and periosteal blood supply to the bone.

PEDICLE DISSECTION

Attention is then drawn to completion of the outline of the skin paddle over the triangular space and dissection down to the circumflex scapula vascular pedicle under direct

vision. More proximal dissection of the vascular pedicle continues until the origin of the CSA and CSV from the subscapular vessels is encountered. The thoracodorsal vessels should become apparent at this point. The bone and skin paddle are then assessed for perfusion and pedicle division follows just distal to the takeoff of the thoracodorsal vessels. Greater pedicle length may be achieved by sacrificing the thoracodorsal vessels and dividing the pedicle at the origin of the subscapular vessels from the axillary artery and vein.

DONOR SITE CLOSURE

Wound closure follows with reattachment of the teres major to the remaining body of scapula through drill holes and thick vicryl sutures. A large calibre vacuum suction drain is placed and the wound margins are approximated primarily and skin is sutured or stapled. Gauze dressings are placed over the wound and the flap is transferred to the head and neck recipient site for insetting after copious irrigation of the flap vascular system with heparinized saline.

PARASCAPULA FLAP

Harvesting of the parascapular fasciocutaneous flap begins in a similar fashion to that of the osteocutaneous flap described above with an exception that this flap is based over the descending cutaneous branch and does not include bone.

Identification of the cutaneous branch is performed with handheld pencil Doppler and an appropriate-sized skin paddle is outlined over this vessel including the point of emergence of the CSA through the triangular space.

Skin paddle elevation begins caudally and progresses in a subfascial plane to ensure the descending branch is captured with the skin flap. As the triangular space is encountered and confirmed through the identification of the upper border of teres major, the transverse cutaneous branch should become apparent at which point it can be divided once the CSA is visualized. The outline of the skin paddle is then completed and pedicle dissection in a retrograde direction follows until the origin of the circumflex scapula pedicle is identified arising from the subscapular vessels. Pedicle division may be performed at this point or more proximally at the origin of the subscapular vessels from the axillary artery and vein if greater pedicle length is needed.

POST-OPERATIVE CARE

The scapula donor site is associated with relatively little morbidity.

The upper extremity and shoulder girdle should be immobilized in the immediate post-operative period with a splint similar to patients splinted for clavicle fractures. This reduces patient discomfort and total analgesic requirements.

Physical therapy is initiated usually after 5 days to prevent shoulder and upper extremity stiffness.

Long-term physical therapy must be instituted in the ensuing 2–3 weeks to prevent chronic restriction in range of motion of the shoulder girdle.

General patient mobilization from bed usually occurs on the third post-operative day but varies based on individual unit protocols.

COMPLICATIONS

Shoulder joint violation. Particular attention must be made to avoidance of entry into the glenohumeral joint potentially resulting in significant articular injury, haemarthrosis and long-term joint dysfunction.

Haematoma. Meticulous attention to haemostasis is paramount specifically dealing with bleeding from the scapula bone edges and transected musculature.

Seroma. Meticulous layered wound closure and placement of large calibre vacuum suction drains and pressure dressings to minimize dead space often prevents this. Drains should only be removed when minimal output is seen.

Long thoracic nerve injury. Injury to this nerve is uncommon and usually occurs with overzealous dissection deep to teres major and latissimus dorsi where it passes to innervate serratus anterior resulting in scapula winging.

Chronic shoulder weakness/dysfunction. Limited shoulder mobility and range of movement can result from poor reapproximation of teres major to the remaining scapula and inadvertent division of teres minor more cephalad.

Lung injury/pneumothorax. This complication should not occur and is preventable if protective retractors are placed deep to the scapula during the performance of bone cuts.

Top tips

- The use of handheld pencil Dopplers markedly improves the localization of the transverse and descending cutaneous branches thus maximizing perfusion to the harvested skin paddle.
- Where bilateral neck dissection is not warranted patient positioning in a lateral position at the beginning of the case provides adequate exposure for neck dissection and tumour ablation followed by scapula harvest without the need for multiple intra-operative patient repositioning thus significantly reducing total operative time.
- Significant increases in pedicle length may be achieved by proximal pedicle dissection to the origin of the subscapular vessels from their corresponding axillary artery and vein.
- Timely institution of physical therapy following the acute post-operative period minimizes shoulder dysfunction and limitations in movement.

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23

Rectus abdominis

JOSHUA E LUBEK

CONTENTS

INTRODUCTION

The rectus abdominis free flap is a versatile myocutaneous flap based upon the deep inferior epigastric artery and its associated vena comitans. The flap was first described by Drever in 1977, as the 'epigastric island flap' and later adapted for breast reconstruction.[1] Credit is also given to Mathes and Bostwick for their use in abdominal wall reconstruction during that same year.[2]

The flap has been well described for its use in reconstruction of large volume defects of the head and neck. Advantages of the flap include ease of harvest, two-team approach and a long vascular pedicle with a large vessel diameter. A large skin paddle with adequate bulk can be provided with minimal donor site morbidity. The flap can also be harvested based solely upon the perforating vessels traversing the rectus muscle within the periumbilical region. The deep inferior epigastric muscle-sparing perforator flap (DIEP) variant, originally described by Koshima and Soeda in 1989, has continued to increase in popularity due to its theoretic decreased risk of abdominal wall herniation, bulge and post-operative pain.[3,4] The rectus abdominis free flap still proves to be a valuable reconstructive tool and should be considered especially in situations requiring large amounts of soft tissue to be transferred.[5–9] This chapter discusses both the rectus abdominis myocutaneous free flap and the DIEP flap for use in head and neck reconstruction.

INDICATIONS/APPLICATIONS

General

The rectus abdominis flap is a reliable flap that can be used for reconstruction of large defects of the head and neck. General advantages include a large caliber artery and associated vena comitans (2–4 mm), long pedicle length (8–10 cm), consistent anatomy and a two-team approach. Nakatsuka et al. reported on their extensive series of 2372 free flaps for head and neck reconstruction over 23 years. The rectus abdominis flap proved to be the most frequently utilized (n = 784) free flap.[5] The authors' explanation for this choice of flap selection was due to its low rate of flap necrosis and ease of use in reconstruction of the head and neck. Although donor site morbidities such as hernia, abdominal wall bulging and pain are generally considered to be of a low risk, the option to use a muscle sparing DIEP flap for the avoidance of such complications, can be utilized.[4,6–8,10] This flap involves harvest of only the skin and subcutaneous tissue based upon the deep inferior epigastric artery. Woodworth et al. reported on a series of 11 DIEP flaps used for large volume defects of the head and neck with the most common sites being either subtotal glossectomy or skin defects.[8] Leonhardt et al.[9] published a case series on 10 DIEP flaps for reconstruction of the maxillofacial region with a defect size ranging from 40–180 cm^2. In a systematic review comparing donor site

morbidity of the abdominis myocutaneous flap and the DIEP flap, Sailon et al. reported that there was no significant difference with respect to abdominal bulge with these two flaps (11% versus 8%, respectively).[10] In another very large series of 1507 breast reconstruction patients comparing the transverse rectus abdominis myocutaneous flap (TRAM) versus the muscle sparing or DIEP flap the overall risk of hernia or muscle bulge was 5.9%.[4] The authors also reported that the risk increased with the amount of rectus fascia harvested and was significantly decreased with the use of a mesh.

Radical maxillectomy/orbital exenteration

Although computer-assisted reconstruction/3D-modelling along with improved techniques in free vascularized bone flaps have allowed for advancements in maxillary reconstruction, large volume soft-tissue free flaps such as the rectus abdominis prove useful in extended maxillary/orbital reconstruction.[11–13] The bulky soft-tissue flap is easy to inset without associated vessel geometric problems, allowing for adequate defect obturation. This will provide acceptable facial esthetics and adequate speech and swallowing function without the need for a prosthetic obturator. Pryor et al. reported on a series of 13 patients reconstructed with the rectus abdominis free flap for such defects. The authors reported that cosmetic results were acceptable to both patient and surgeon whilst meeting the goal of successful obturation of the maxillectomy defect without the need for oral cavity defect care[12] (see Figure 23.1a through c).

Skull base reconstruction

Tumours involving the anterior skull base may require both resection of hard and soft tissue. The defect created will result in a communication between the intracranial space and the paranasal sinuses/nasopharynx. Goals of skull base reconstruction include the creation of a watertight dural seal and the separation of the paranasal sinuses from the neurocranium. This separation is important to prevent cerebrospinal fluid (CSF) leak, meningitis, pneumocephalus or brain herniation. Smaller defects can very often be repaired with local flaps such as pericranial flaps or autologous bone grafts. Large defects especially those in combination with orbital exenteration are best reconstructed with vascularized bulky soft-tissue flaps.[13]

Subtotal/total glossectomy

A large amount of tissue is required to restore bulk in total/subtotal glossectomy defects. This bulk allows for improved swallow and speech function whilst providing obliteration of dead space to help prevent an orocutaneous fistula. The anterior rectus fascia can also be used to suspend the floor of mouth by suture to the inferior border of the mandible.[5–9] Haddock et al. reported on a series of eight patients reconstructed with the rectus abdominis flap for total/subtotal glossectomy defects

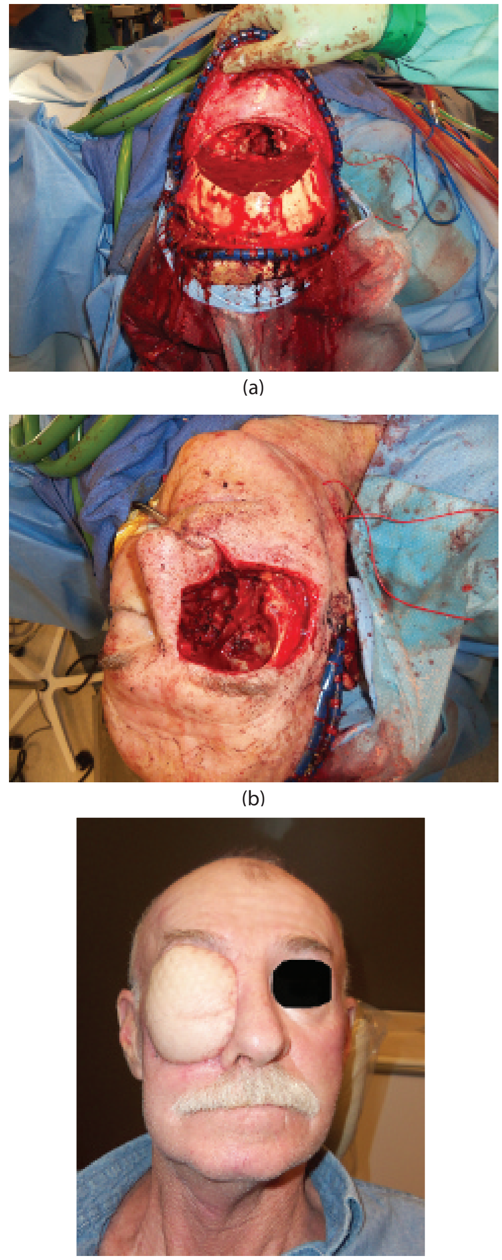
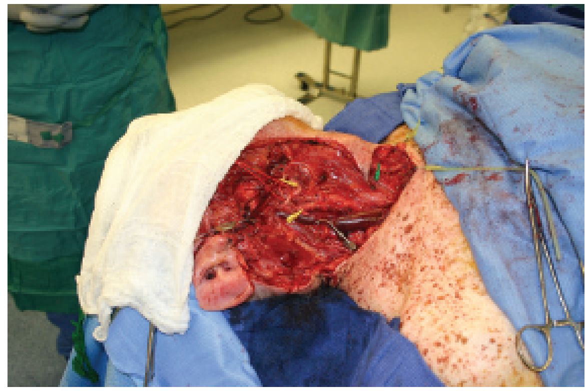


Figure 23.1 (a) Squamous carcinoma of the orbit and ethmoid sinuses requiring orbital exenteration and craniofacial resection. Communication with the neurocranium depicted. (b) Squamous carcinoma of the orbit and ethmoid sinuses requiring orbital exenteration and craniofacial resection. Orbital defect depicted. (c) Reconstructed craniofacial resection/orbital exenteration with a rectus abdominis free flap.

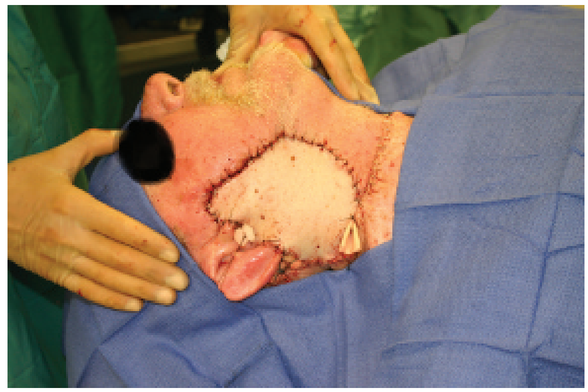
in which the muscle/fascia was secured to the lingual mucosa for suspension of the flap. The authors' reported that at 1-year follow-up, all patients tolerated an oral diet without evidence of aspiration whilst maintaining intelligible speech.[14]

Large skin defects

Large defects of the facial skin, cheek and neck can be reconstructed with the rectus abdominis flap.[5,15] If thinning of the flap is required for a more esthetic facial contour, one can either consider a DIEP flap or immediate debulking of the subcutaneous tissue whilst taking care to preserve a cuff of tissue surrounding the perforator. Secondary contouring procedures for bulky rectus flaps are also a safe option at a later time interval. The rectus abdominis flap can also be used for reconstruction of large scalp defects; however, the large, broad-base, flat latissimus dorsi muscle only free flap with an overlying skin graft is generally preferred for this type of defect.[15] Although the rectus abdominis flap is considered a bulky flap that some consider difficult to fold, complex defects such as full thickness defects involving the skin of the cheek and oral mucosa have been reconstructed with this flap. Patel et al. reported on a series of 46 patients with a complex head and neck defect (external skin and intra-oral component) successfully reconstructed using a multi-island vertical rectus abdominis myocutaneous free flap[16] (see Figure 23.2a and b).



(a)



(b)

Figure 23.2 (a) Cutaneous squamous carcinoma involving the pre-auricular region, parotid gland and neck. (b) Large cutaneous defect reconstructed with a deep inferior epigastric artery (DIEP) perforator flap.

RELEVANT ANATOMY

The rectus abdominis muscle is a strap-like vertical muscle, approximately 30 cm in length by 6 cm in width, originating from the symphysis pubis and inserts into the 5th, 6th and 7th costal cartilages along with the xiphoid process. The muscle is enveloped by a tough rectus sheath, formed by the fascia of the three abdominal wall muscles (external/internal oblique and the transversalis abdominis muscles) originating at the linea semilunaris. The aponeurosis in the midline adjoining the two rectus muscles is known as the linea alba. The rectus sheath splits into an anterior and posterior sheath to surround the rectus abdominis muscle. The posterior rectus sheath ends abruptly at the arcuate line at the level of the anterior superior iliac spine bilaterally. Below this line, there only exists an anterior rectus sheath and deep to the rectus muscle is a thin layer of tissue through which the preperitoneal fat is easily identified.

The dual vascular supply to the rectus abdominis muscle is based upon the deep superior and inferior epigastric arteries. Rectus flaps for head and neck reconstruction are largely based upon the deep inferior epigastric vessels due to increased pedicle length, larger vessel caliber, anatomic reliability due to skin vasculature based upon the musculocutaneous perforators from the inferior epigastric vessels and anterograde venous outflow of the flap.[17]

The deep inferior epigastric artery is a large caliber vessel (3–4 mm diameter) that travels on the deep surface of the rectus abdominis muscle. The vessel splits into two main branches as it courses the undersurface of the muscle greater than 50% of the time. From the point that the artery exits the muscle at the level of the arcuate line travelling inferiorly for approximately 8–10 cm, it inserts into the medial aspect of the external iliac artery. Paired vena comitans accompanying the artery will commonly form into a single larger caliber vein (greater than 60%) and enter into the external iliac vein.

The perforators to the skin are most often (80%) situated in a 3–5 cm area surrounding umbilicus. These perforators are quite robust (average diameter greater than 0.5 mm). The perforators identified at the level of the umbilicus and inferiorly are supplied by the deep inferior epigastric vessels forming the basis the rectus abdominis/DIEP flap for head and neck reconstruction (see Figure 23.3).

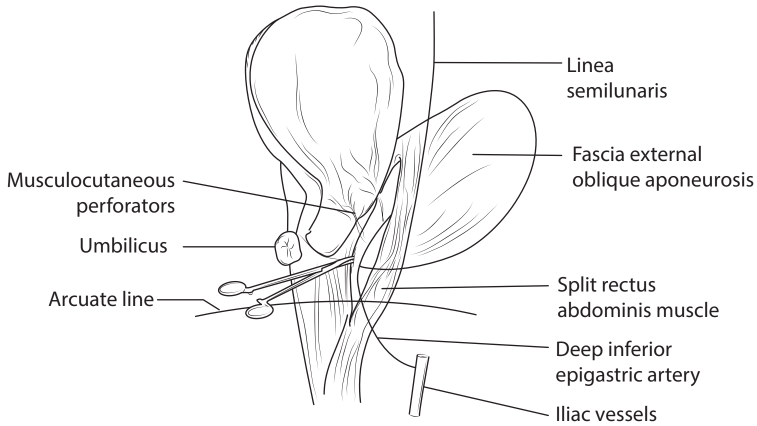


Figure 23.3 DIEP flap. Musculocutaneous perforators identified travelling from the pedicle through the rectus muscle and into the subcutaneous tissue. Perforator dissection towards the pedicle by dividing the rectus abdominis muscle with preservation of the majority of the rectus abdominis muscle.

Innervation to the rectus abdominis muscle and its overlying skin is supplied by the lower six thoracic ventral rami and exiting T6–T12 thoracic nerves (7–11th intercostal nerves and subcostal nerve). The nerves travel between the transversus abdominis and the internal oblique muscle and enter the rectus muscle on the posterior aspect ultimately piercing the anterior rectus sheath to supply the overlying skin via the cutaneous branches.[1,2,3,6,17]

OPERATIVE TECHNIQUE

Flap design

The skin paddle of the flap can be oriented in a vertical (VRAM) or transverse (TRAM) orientation to the underlying rectus muscle based upon the highly consistent perforators from the deep inferior epigastric artery surrounding the umbilicus. The flap can be extended in an oblique fashion from the peri-umbilical area towards the ipsilateral lower costal margin. Total width of flap harvest is generally guided by the ability for primary closure; however, a skin paddle measuring up to 12 cm × 30 cm can be harvested (especially in the transverse direction). Elevation of the skin paddle in the transverse direction will allow for less muscle to be harvested for a less bulky flap. Disadvantages of the TRAM orientation include a shortened pedicle length and the need to preserve the umbilicus. Although not necessary, the perforators can be identified using a handheld surface Doppler. During dissection only the ipsilateral perforating vessels need to be preserved to ensure viability of the flap (see Figure 23.4).

Landmarks to be identified include the umbilicus, xiphoid process, the inferior costal margin, pubic tubercle, anterior superior iliac spine bilaterally and the iliofemoral pulse at the level of the inguinal ligament (origin of the deep inferior epigastric vessels).

FLAP HARVEST – RECTUS ABDOMINIS MYOCUTANEOUS FLAP

After the appropriate landmarks and skin paddle has been designed, the skin and subcutaneous tissue are incised and dissected from the lateral aspect until the fascia overlying the external oblique muscle is encountered. Continuing in a medial direction, the linea semilunaris is identified and as the flap is gently elevated towards the midline watching carefully for the periumbilical perforators originating through the rectus muscle and supplying the overlying skin and subcutaneous tissue. The anterior rectus sheath is incised laterally to the perforator vessels in a vertical direction identifying the underlying lateral border of the rectus muscle. Incision of the anterior rectus sheath is now performed in a transverse direction ensuring an adequate safe distance both superiorly and inferiorly from the perforator vessels until the linea alba is encountered. The skin paddle is now circumferentially completed on its medial aspect stopping at the linea alba at the midline. The superficial surface of the rectus muscle is also exposed inferiorly below the level of the skin paddle and the perforator vessels. Suturing of the subcutaneous tissue to the underlying muscle with a resorbable suture can help to avoid any risk of shearing of the perforators from the overlying subcutaneous tissue. The rectus muscle is now divided superiorly identifying the posterior rectus sheath. The distal end of the pedicle will be encountered superiorly and ligated with silk ties or hemoclips. The flap can now be raised in an inferior direction, keeping the posterior rectus sheath intact. The linea alba will be incised in the midline, as one continues to identify the medial border of the rectus muscle, elevating the myocutaneous flap off of the posterior rectus sheath. Care must be taken to not enter into the umbilicus and to protect the ipsilateral peri-umbilical perforators. The pedicle can now be easily identified on the undersurface of the

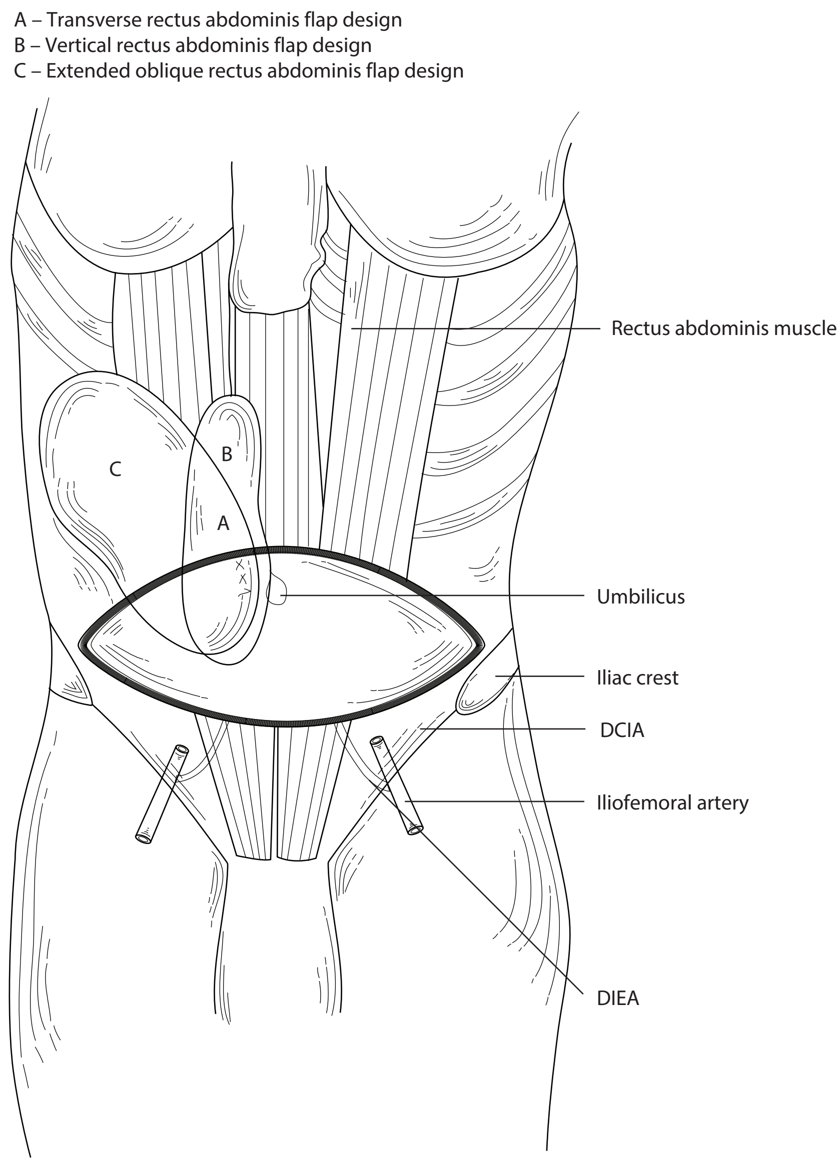


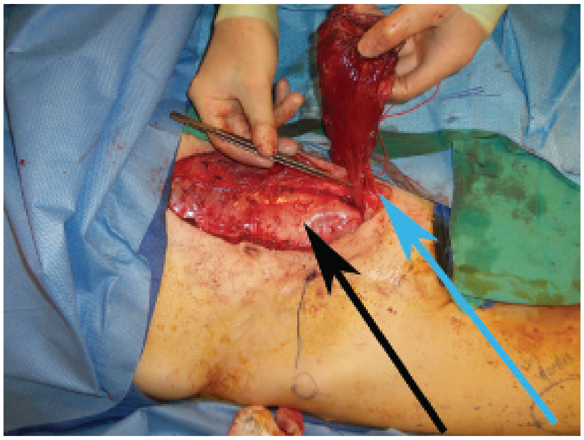
Figure 23.4 Skin paddle design for the rectus abdominis myocutaneous flap. The x identifies the periumbilical perforators. A – Transverse rectus design (TRAM). B – Vertical rectus design (VRAM). C – Extended design for increased soft tissue.

rectus muscle. The rectus muscle will now be divided inferiorly staying above the level of the arcuate line, all the whilst protecting the pedicle of the deep inferior epigastric artery and its vena comitans. The vascular pedicle can now be dissected with instrument or gentle finger dissection as it traverses over the preperitoneal fat/fascia travelling into the inguinal region to join the external iliac vessels (see Figure 23.5a and b).

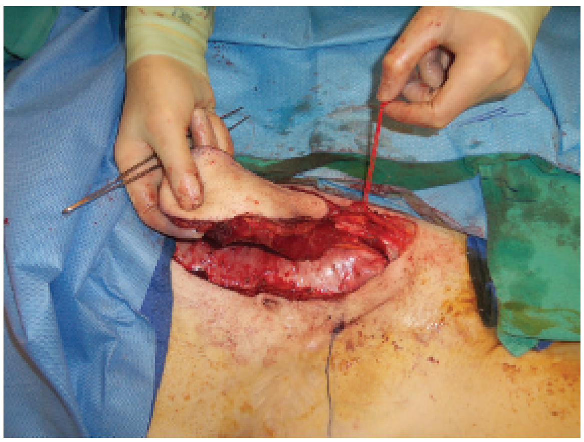
Below the arcuate line, the anterior rectus fascia should be closed with a non-resorbable suture to avoid the risk of hernia or abdominal bulge. If there is loss of integrity of the anterior rectus sheath below the arcuate line, it should be repaired with a synthetic (i.e. prolene) or resorbable (i.e. porcine derivative) mesh sutured to the wound margins. Above this line, the posterior rectus sheath is usually strong enough so that closure of the anterior sheath is not necessary especially if it will result in a tight abdominal wall closure or if one wants to avoid the risk, albeit low of mesh infection. Any violation of the posterior rectus sheath with exposure of the peritoneum should be repaired with a non-resorbable suture once identified.

Closure of the subcutaneous tissue and skin is usually quite easily done without the need for tissue undermining. A suction drain should be placed to help minimize the risk of haematoma or seroma formation (see Figures 23.3 and 23.6).

An alternative technique of harvesting the rectus abdominis myocutaneous does not involve identification of the perforator vessels but rather incision of the lateral and medial aspects of the anterior rectus sheath once it is initially encountered. There is less risk of perforator vessel shearing with this technique; however, a larger patch of anterior rectus sheath is required with possible risk of increased abdominal wall weakness.



(a)



(b)

Figure 23.5 (a) Harvest of the rectus abdominis myocutaneous free flap. Blue arrow marks: the superficial epigastric vessels which do not need to be preserved but can also perfuse and provide venous flap drainage. Instrument pointing to the pedicle of the deep inferior epigastric vessels. Black arrow marks: the distal extent of the posterior rectus sheath. Line drawn on the abdomen demarcates the arcuate line. (b) Harvest of the rectus abdominis myocutaneous flap. Vessel loop around the superficial epigastric vessels.

FLAP HARVEST – DIEP FLAP

Flap design and dissection proceed as per the standard rectus abdominis myocutaneous flap until the periumbilical perforator vessels are encountered exiting through the anterior rectus fascia towards the subcutaneous tissue. The fascia is incised around the perforators, keeping a small cuff of this fascia circumferentially around the selected perforator for its protection. The remaining anterior sheath is incised in a vertical fashion exposing the entire underlying superficial surface of the rectus muscle. Dissection proceeds carefully unroofing the perforator vessel through the rectus muscle until the pedicle of the deep inferior epigastric vessels are encountered. Multiple perforators can be captured with this technique; however, generally one large perforator is sufficient to perfuse the flap. To avoid any twisting or damage to the perforator vessels, a connecting cuff of muscle can be preserved between the selected perforators. Once fully exposed on its lateral surface, the vascular pedicle can be ligated superiorly away from the point at which the perforator joins the pedicle. The remainder of the skin paddle can be elevated on its medial and inferior aspect with care to identify and protect the perforator vessels as they are encountered from this direction. Perforator dissection is completed on the backside/medial aspect through the rectus muscle until the pedicle is encountered. Branching vessels into the muscle can be ligated with hemoclips or bipolar cautery. Segmental motor nerves encountered deep in the rectus muscle and deep to the pedicle can be preserved. The vascular pedicle is now dissected inferiorly as in the standard myocutaneous flap within the preperitoneal fat until the desired pedicle length is achieved or the origin point at the external iliac vessels is encountered[8] (see Figure 23.7).

A layered closure is achieved with the rectus muscle re-approximated with a resorbable suture and the anterior rectus fascia closed with a non-resorbable suture.

Figure 23.6 Rectus abdominis myocutaneous flap donor site post-operatively.

POST-OPERATIVE CARE

Standard free flap monitoring should be performed per specific surgical unit protocol with intensive flap monitoring for the first 72 hours following surgery. Methods of monitoring include assessment of arterial and venous Doppler signal, flap color, temperature and quality of bleeding on scratch test. Various methods of anti-coagulation (i.e. aspirin, heparin, dextran) are also surgeon specific;

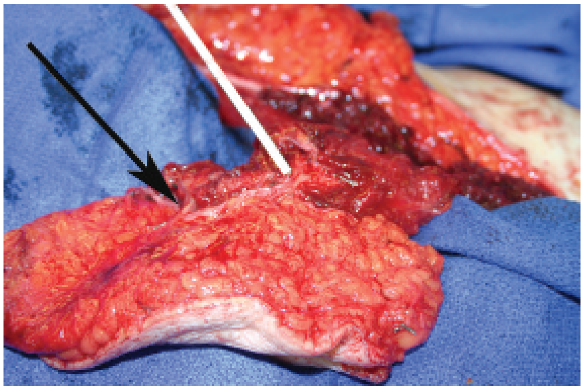


Figure 23.7 Deep inferior epigastric artery perforator flap. Two musculocutaneous perfortaors are identified (black arrow and Doppler probe placed on the second perforator). A small cuff of muscle is preserved inferiorly protecting the pedicle.

however, there is very little level I (prospective, randomized, blinded controlled-trials) evidence to suggest their clinical efficacy.[18,19]

An abdominal binder may be used for added patient comfort and avoidance of heavy lifting should be followed for approximately 2 months to avoid the risk of hernia or wound dehiscence. Although the peritoneum is generally not violated during harvest of the rectus abdominis flap, bowel sounds should be assessed prior to starting a diet due to the risk of ileus. Peri-operative antibiotics should be administered per standard protocols generally for a period ranging from 24 to 48 hours post-operatively. Donor site wound infection is low and ranges from 3% without a mesh up to 5% with a mesh.[20] Drains can be removed early with risk of seroma and haematoma formation ranging up to 8%.[21] Early mobilization is useful to help prevent risk of pneumonia and deep venous thrombosis. Post-operative atelectasis/pulmonary complications can occur as a result of pain associated from the dissection of the abdominal wall muscles or as a result of a tight abdominal wall closure. Lo et al. evaluated 55 patients who underwent head and neck reconstruction with the rectus abdominis free flap. The authors recommend the use of a mesh closure if the anterior rectus sheath was to be completely closed to help reduce the risk of significant post-operative atelectasis.[22]

Top tips

- Previous ventral hernia or significant abdominal surgery involving the ipsilateral side is a contra-indication to flap harvest.
- Widening of the paired rectus muscles at the midline (widened linea alba) secondary to previous surgery or abdominal wall weakness can cause the cutaneous perforators to appear more laterally positioned. Only perforating vessels lateral to the linea semilunaris can be safely ligated.
- DIEP flap can be harvested with a small cuff of muscle (especially if multiple perforators harvested) to protect the cutaneous perforators and avoid vessel kinking or twisting.
- The rectus abdominis flap may be too bulky in the morbidly obese patient.
- TRAM (transverse flap) allows for a more esthetic closure.
- Avoid elevating the flap below arcuate line to avoid risk of abdominal bulge and hernia.

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24

Latissimus dorsi flap

ANDREW W BAKER

CONTENTS

DEVELOPMENT

- The first musculocutaneous flap described in the medical text by Tansini in 1896.
- Initially used for the primary reconstruction of the post mastectomy defect.
- The first use of a pedicled latissimus dorsi flap for reconstruction in the head and neck area was described by Quillen in 1978.
- Watson reported the first successful microvascular transfer of a free latissimus flap in 1979, and exploited a wide variety of applications for head and neck reconstruction.

FEATURES

There has been a subtle resurgence in the utilization of regional flaps in reconstruction of the head and neck surgical defect, indeed free tissue transfer may not be the first choice for a range of clinical situations. Indeed as the range of pathologies which produce defects in the head and neck evolves, there remains a continued validity for this versatile myofascial flap.

This is a popular donor site for the transfer of tissue to the head and neck region because of the following:

- The ease of dissection
- The long length and wide diameter of the vascular pedicle, rarely compromised by arteriosclerosis
- The flap can be raised as a pedicled or free flap.
- The length of the vascular pedicle gives this flap potential to reconstruct defects anywhere in the head and neck.
- The large surface area of muscle-only or musculocutaneous flap available.
- Bone may be included in the flap, most elegantly by inclusion of the angular branch artery to the tip of scapular.
- Minimal donor site morbidity.
- Access to the dissection requires turning and usually prohibits simultaneous harvest.

The latissimus dorsi is a large broad flat muscle that covers the posterior inferior portion of the trunk (Figure 24.1).

It has a broad and crescentic origin from the lower four ribs; the spinous processes of the lower six thoracic vertebrae; the thoracolumbar fascia and laterally it also arises from the fascia that is attached to the iliac crest.

The muscle curves around the lower border of the teres major, and is twisted upon itself, so that the superior fibers become at first posterior and then inferior, and the vertical fibers at first anterior and then superior.

The muscle terminates as quadrilateral tendon, about 7 cm long, which passes in front of the tendon of the teres major, and is inserted into the bottom of the intertubercular groove of the humerus; its insertion extends higher on the humerus than that of the tendon of the pectoralis major.

The lower border of this tendon is united with that of the teres major, the surfaces of the two being separated near their insertions by a bursa; another bursa is sometimes

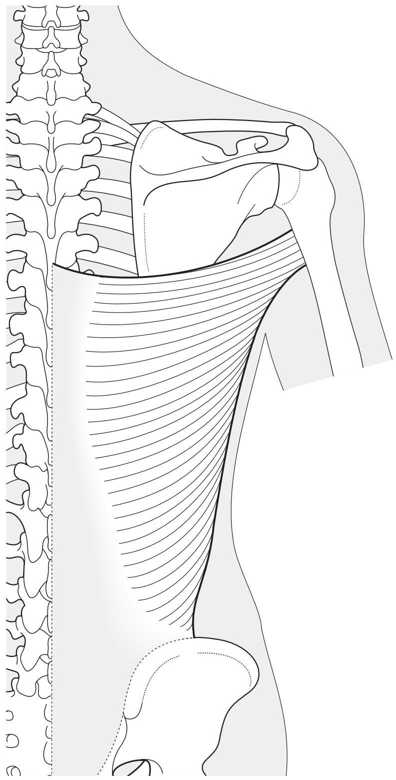

Figure 24.1 Anatomy of the latissimus dorsi muscle.

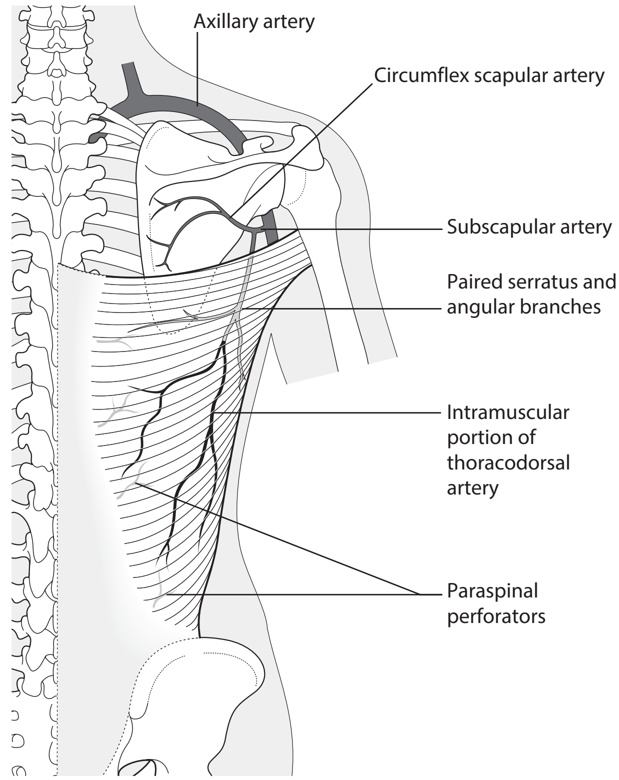

Figure 24.2 Key branches of the vascular supply to the latissimus dorsi muscle.

interposed between the muscle and the inferior angle of the scapula.

NEUROVASCULAR ANATOMY

The main superior pedicle of the muscle is the thoracodorsal artery and vein, which eventually supplies a rich network of musculocutaneous perforators, particularly over the anterior border of the muscle. It should be noted that as a type 5 muscle, there are a further two minor vascular supplies and therefore angiosomes supplied by the posterior intercostal segmental perforators in the mid portion and the lumber artery segmental perforators in the distal paraspinal area (Figure 24.2).

The thoracodorsal vessels are terminal branches of the subscapular artery and vein which arise from the third part of the axillary vessels. These vessels initially run inferiorly through the axilla, and then for a short distance below the latissimus dorsi muscle before penetrating the muscle at the vascular hilum. At this point, the vein can be identified laterally with the artery medial and the thoracodorsal nerve being sandwiched between the two. In its extra-muscular course there are branches to subscapularis, teres major and serratus anterior and the important angular branch to the tip of the scapular. Just within the muscle, the vessels typically bifurcate into transverse and longitudinal branches. The transverse branch is running at an average of 3.5 cm below the upper border of the muscle and the longitudinal branch usually 2.0 cm from the lateral edge. This feature allows the potential development of two separate skin paddles.

- The average diameter of the thoracodorsal artery is 2.5 mm, the diameter of the vein is 3.5 mm.
- The length of the pedicle is between 6 and 16 cm.
- By extending the dissection proximally to the origin of the subscapular vessels at the axillary artery, the subscapular artery pedicle can provide a diameter of 6 mm on average. The pedicle length is also extended by a least 4 cm.

The thoracodorsal nerve supplies the motor innervation to the latissimus dorsi. It arises from the posterior segment of the brachial plexus. It enters the axilla from behind the axillary vessels and then descends with the thoracodorsal artery and vein to the neurovascular hilum. The thoracodorsal nerve usually crosses the axillary vessels approximately 3 cm proximal to the subscapular artery and vein.

FLAP DESIGN AND UTILIZATION

The length of the pedicle is generous and even as a pedicled flap, most defects of the head and neck area can be reached after the flap is passed through the axilla and then between the pectoralis minor and major muscles of the chest wall. By exteriorizing the pedicle, even posterior scalp defects may be reconstructed.

Division of the arterial branches to the serratus anterior prevents inferior tethering of the thoracodorsal pedicle.

Complete isolation of the pedicle by division of the circumflex scapular branch can be achieved. However, once this is performed then there is no mechanical method to stop rotation and kinking of the pedicle as it arises from the axillary artery. Complete transaction of the tendon of the latissimus dorsi at the superior insertion provides an ultimate freedom of rotation.

Fashioning the skin paddle over the distal portion of the muscle can extend the flap's reach, but here it should be noted that, unlike the number of perforators at the anterior edge of the muscle in the distal territories the density of musculocutaneous perforators is much reduced and thus viability of the skin is potentially reduced. Additionally it should be appreciated that the blood supply to the skin in this area will have had to cross at least one angiosome via choke vessels, further compromising the viability of the distal skin (Figure 24.3).

The total area covered by the latissimus dorsi muscle is approximately 25 cm × 40 cm. The maximum size of the skin paddle that can be transferred is naturally determined by the size of the particular patient. Although the defect can be skin grafted, rarely is this advised or required.

Through and through defects of the head and neck involving skin and mucosa can be reconstructed by folding and de-epithelializing a portion of a single large latissimus dorsi musculocutaneous paddle or by using two separate musculocutaneous paddles based on the transverse and descending branches as described by Tobin in 1981.

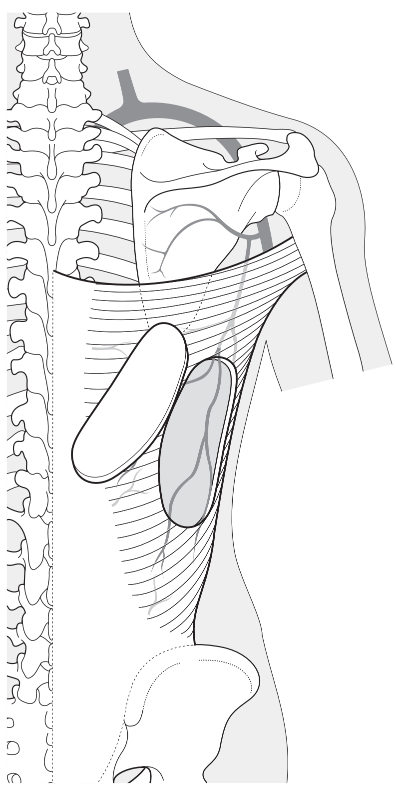

Figure 24.3 The two skin paddles can be based on the transverse or vertical limbs of the thoracodorsal artery. However, the highest density of perforators favours the anterior edge of the muscle, as indicated.

The early 1980s saw much interest in the potential development of the vascularized bone transfer with the latissimus dorsi flap and rib. This was based on experimental radio-opaque injection studies of the subscapular vessels in dogs which suggested retrograde filling of the posterior intercostal perforators and therefore potential blood supply to dorsal aspects of the fifth to tenth ribs. Very few examples exist in the literature of this demanding technique.

The way forward for bone transfer came with the important clarification of the angular branch of the thoracodorsal artery by Coleman and Taylor in 1991. This study defined a separate vascular supply to the caudal tip of the scapular. This finding not only provided evidence of a separate vascular supply of the scapular tip for the scapular flap system, but importantly provides a dependable segment of bone for use in a thoracodorsal flap setting. Gilbert has since refined the clinical application of this technique, using the scapular tip for maxillary reconstruction.

Harii and co-workers have continued to evolve the use of the latissimus dorsi flap in facial reanimation. The advantages of the latissimus dorsi for this procedure are based on the length and calibre of the neurovascular pedicle and its division into two segments. This allows the transfer of two separate muscle units. One unit being used for reanimation of the mouth and the other, for the lower eyelid. The latissimus dorsi musculocutaneous flap has also been used for dynamic reconstruction of composite cheek defects that include the loss of the mimetic muscles of the midface. In this case, the musculocutaneous unit is transferred and revascularized and the thoracodorsal nerve is anastomosed to the ipsilateral facial nerve.

The use of innervated latissimus dorsi flap for the dynamic reconstruction of the tongue, following glossectomy has been proposed. However, it is accepted that duplication of the complexity of the tongue's musculature in both form and function by a simple muscle flap consisting of fibres running in one direction is limited. Haughey and Frederickson described the use of the re-innervated latissimus dorsi musculocutaneous flap for total tongue reconstruction. The thoracodorsal nerve was anastomosed to the cut end of the hypoglossal nerve. In this and subsequent studies useful tone without purposeful movement could be demonstrated in the neo-tongue.

Watson and Lendrum reported a one-stage tubed latissimus dorsi flap for circumferential pharyngo-esophageal reconstruction. Watson described several technical considerations in using the latissimus dorsi flap for pharyngeal defects. The authors advised transferring a large segment of muscle around the circumference of the skin paddle, this skin paddle is folded upon itself and sutured together to form a tube, the neopharynx. The muscle was sutured around the tube and to the surrounding tissues to provide a second-layer seal (Figure 24.4).

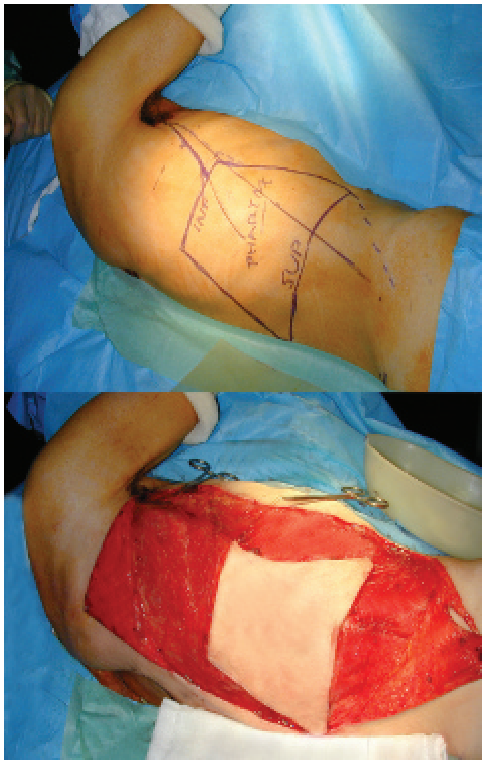

Figure 24.4 The skin paddle is marked to provide the epithelial layer for pharynx reconstruction. This is harvested on the complete muscle to provide optimal skin perforators and a secure second layer seal.

Kim in 2003 proposed the Latissimus dorsi perforator flap. The concept allows harvest of vast areas of trunk skin, without the necessity of simultaneous muscle harvest. The musculocutaneous perforators are dissected free of the muscle, on their course to the skin. Indeed it has been suggested that a large skin paddle may be sustained by the inclusion of a singular perforating vessel group. This versatile variation of the latissimus dorsi flap is a popular contemporary solution to the demanding post-mastectomy defect; this refinement is also ideal in head and neck reconstruction as it can provide plentiful thin pliable tissue.

PRE-OPERATIVE ASSESSMENT

It is useful to assess the patient pre-operatively, and the muscle can be easily visualized by pushing with the outstretched arm against a wall. Note should be made of previous axillary surgery, as this may have already compromised the thoracodorsal vessels. The anterior border of the latissimus dorsi can be readily palpated in a thin patient, as it descends out of the posterior axillary fold, laterally on the trunk. Localization of the arterial supply with Doppler probes is not necessary.

FLAP HARVESTING TECHNIQUE

Typically the patient is usually turned into the lateral decubitus position. The ipsilateral arm is prepared and draped together with the lateral thorax, shoulder, axilla and back. The anterior border of the latissimus dorsi is marked on the patient as a line between the posterior axillary fold and a point halfway between the anterior superior iliac spine and the posterior superior iliac spine. On this line, approximately 2 cm below the level of the tip of the scapula is where the vessels penetrate the muscle and divide into the horizontal branch, which runs a few centimetres below the scapula tip, and a more vertically directed branch, which runs 3–4 cm posterior to the anterior edge of the muscle. A skin paddle should be centred over one of these main branches, preferably over the vertical limb which bears the highest density of skin perforators (Figure 24.5).

The initial incision is made from the axilla along the marked line or cutaneous paddle. Deeper dissection along the same line allows the identification the anterior leading edge of the latissimus dorsi muscle.

Superiorly, the pedicle can be found within the adipose tissue of the axilla. This then descends on the lateral thoracic wall to provide muscular branches and the angular branch to the scapula before entering the hilum of the latissimus dorsi. By retracting the free edge of latissimus dorsi, the extra-muscular pedicle can be identified by tracing the

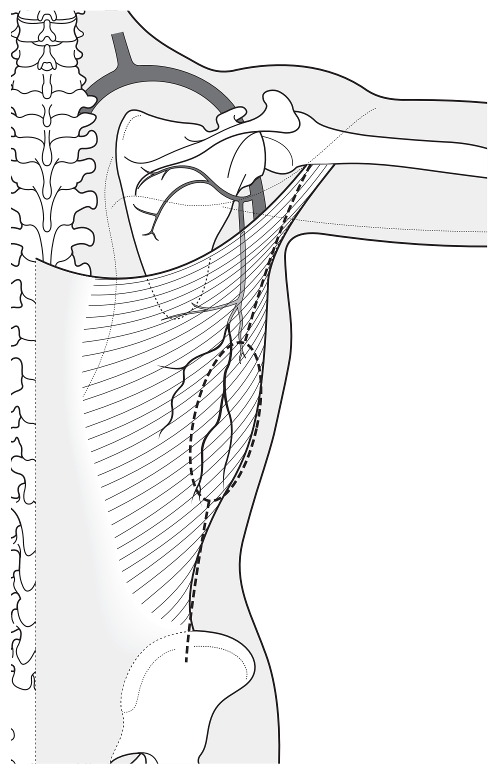

Figure 24.5 Anterior border of the latissimus dorsi is marked on the patient as a line between the posterior axillary fold and a point halfway between the anterior superior iliac spine and the posterior superior iliac spine.

last extra-muscular branch to the serratus anterior back to the main vascular pedicle. It is important to note that typically, the branch to the angle of the scapula also arises at this same level (Figure 24.6). After careful recognition of the pedicle, these opposing branches are ligated and secured so that significant cranial mobilization of the flap can continue. Depending on the requirements of the flap, the whole or part of the muscle is harvested by dissection from the chest wall and surrounding muscles.

Cutting the muscle to determine the paddle size can be assisted by the use of a GIA linear stapler. The device produces a clean, bloodless edge, which is easily suture in the receipiant site (Figure 24.7).

Complete mobilization of the latissimus dorsi requires transection of the tendinous insertion to the humerus. This manoeuvre should be performed with caution whilst protecting the vascular pedicle and keeping it under direct vision.

Passage of the pedicled flap requires preparation of a tunnel between the pectoralis major and minor muscles. The lateral edge of these muscles is identified in the deep part of the anterior axilla through the superior aspect of the incision.

A carefully placed neck dissection incision can facilitate delivery of the pedicle in to the neck, alternatively an incision parallel and inferior to the clavicle may be required to access the pedicle through the tunnel. Naturally a passage through pectoralis major, at the muscular insertion at the clavicle is required, it is critical that space for the vascular pedicle should be generous (Figure 24.8).

Carefully, the latissimus dorsi flap is passed through the tunnel whilst maintaining the pedicles' orientation and being certain not to twist or kink the pedicle.

Primary closure of the donor site can usually be accomplished by widely undermining the adjacent skin edges. A number of deep tension sutures may be required to stabilize the wound closure. This careful layered closure should be accompanied by adequate suction drainage.

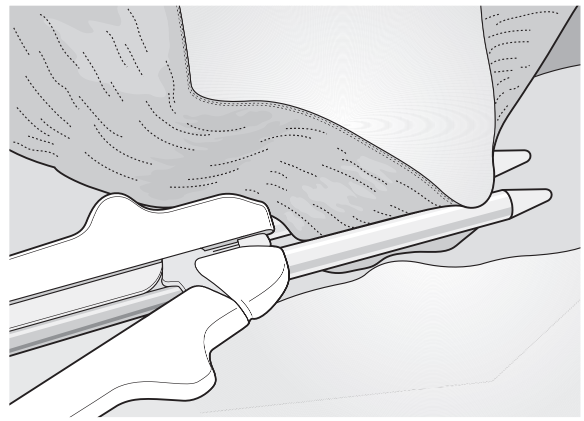

Figure 24.7 Gastrointestinal anastomosis (GIA) linear stapling device to cut and control bleeding from the muscle.

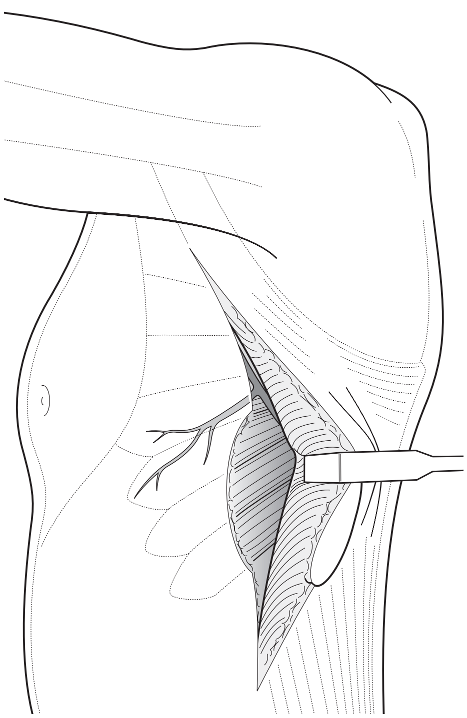

Figure 24.6 By retracting the free edge of latissimus dorsi, the extra-muscular pedicle can be identified by tracing the last extra-muscular branch to the serratus anterior back to the main vessel.

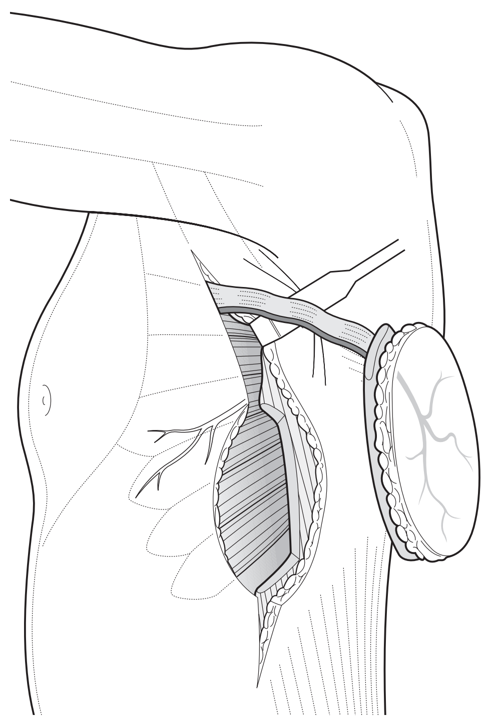

Figure 24.8 With the pedicle isolated and the muscle and skin flap elevated, the flap is ready for delivery to the neck.

Top tips

- The latissimus dorsi flap can be used either as a pedicled flap or as a free flap.
- The pedicle is very long and the flap will reach the orbit if necessary.
- The pedicle can be used to protect the carotid artery in irradiated necks.
- A major disadvantage is that the patient must be turned whilst the flap is harvested.

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25

Anterolateral thigh flap

ANDREW LYONS

CONTENTS

PRINCIPLES AND JUSTIFICATION

The anterolateral thigh flap is a perforator flap (Figure 25.1). A perforator flap is a flap of skin or subcutaneous tissue which is based on the dissection of a perforating vessel. A perforating vessel or, in short, a perforator, is a vessel that has its origin in one of the axial vessels of the body. It passes through certain structural elements of the body besides interstitial connective tissue and fat before reaching the subcutaneous fat layer. As a perforator flap, the anterolateral thigh flap is relatively simple to raise and in most hands has been reported as an extremely reliable flap for a variety of defects. If the flap pedicle is harvested at its junction with the profunda vessels, the artery is typically 4 mm in diameter and the vein 6 mm in diameter, and it is extremely long. The lateral cutaneous nerve can be incorporated for either motor or sensory nerve reconstruction. Like most perforator flaps it has the advantage of not removing a bulk of muscle and of the skin being closed primarily. It can be raised as a free myocutaneous flap and, provided a large enough flap is raised, the distribution of perforators can be ignored. Although in a Western population, the added bulk is seldom necessary this is occasionally a useful option.

INDICATIONS

The anterolateral thigh flap is indicated for the coverage of any soft tissue defect of the head and neck including tubed flaps for laryngeal reconstruction and as an obturator flap for maxillary defects. Although popularized in the Far East as the first choice or default flap for intraoral reconstruction, the apparent increase in flap thickness exhibited in Caucasian–Western populations, particularly females, can make this flap less than ideal for many defects, and its use should be avoided for patients with a BMI higher than 30. Despite the possibility that a flap may be 5 cm thick, this is a very useful flap for larger intraoral defects. The flap thickness may be an advantage in replacing a composite parotid resection, total glossectomy where loss of bulk due to muscle atrophy is not a problem, and in maxillary obturation. According to some authors, fairly radical flap thinning can be undertaken, circumventing the thickness problem, perhaps aided by the use of the operating microscope. However, although some flap thinning can be easily undertaken at the margins of the flap, reduction of the entire flap to say 50% would not be recommended, particularly to surgeons new to this technique. Muscle can be incorporated where a two-layer closure is required, like for fistulas.

PREOPERATIVE

The size and thickness of the proposed defect should be estimated and will indicate whether this flap should be used. The thickness of the flap can be assessed by simply squeezing the skin and subcutaneous tissue in the area of the thigh to be harvested between the thumb and forefingers. If another flap such as the radial forearm

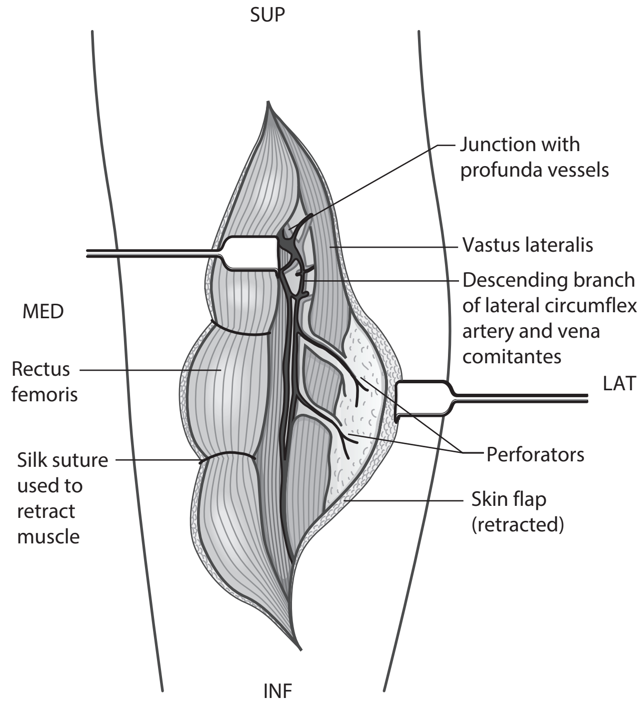

Figure 25.1 Anatomy of anterolateral thigh flap based on descending branch of lateral circumflex femoral artery. LAT, lateral; INF, inferior.

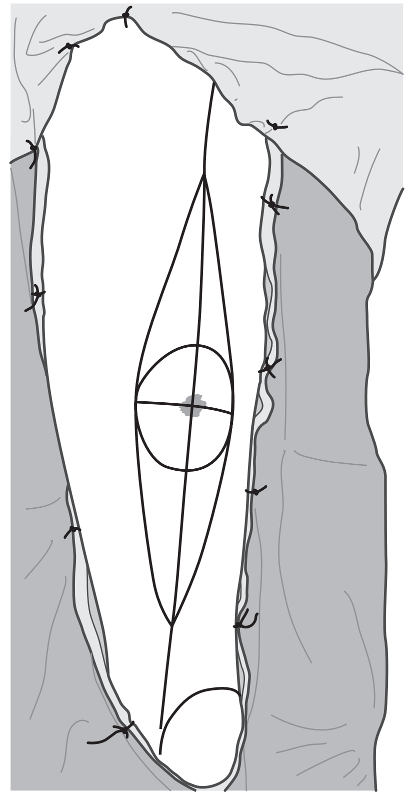

Figure 25.2 Anterolateral thigh flap marked out. Note inferolateral segment of 4 cm radius circle is most likely to contain perforator(s).

flap could be used, to some extent the patient should be offered the choice between the alternative flaps. Even though closed primarily, the donor site scar and thigh dimpling that occur after healing is not ideal and the patient may prefer the defect in the forearm caused by the radial forearm flap. A line is drawn between the anterior superior iliac spine and the lateral border of the patella (Figure 25.2). At a point midway along this line a 4 cm circle is drawn. Perforating vessels are searched for using a 10 MHz handheld Doppler probe, the most common site to find a perforator is in the inferolateral section (Figure 25.3).

Nearly all patients have usable perforators (96%) and a handheld Doppler has a positive predictive value of only 65%, so this is only a guide and should not be a reason for abandoning the flap. Either leg can be used for any defect so the leg that has the loudest perforators should be used. However, all patients should be warned that an alternative flap might have to be utilized.

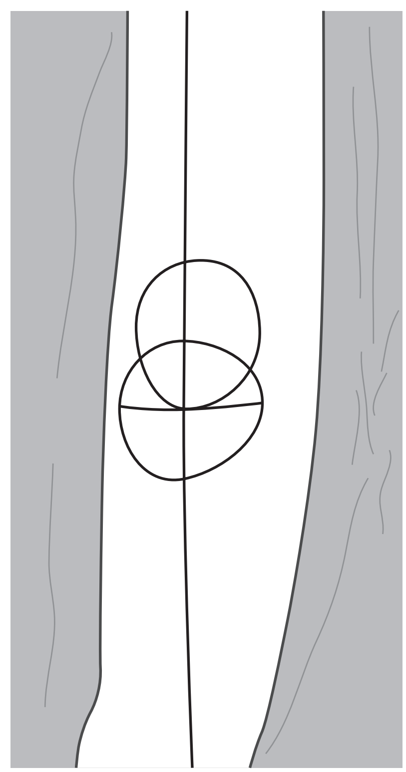

Figure 25.3 After Doppler mapping, this circle that will be included in the flap has been moved 4 cm away from the anterior superior iliac spine, at top left of picture.

OPERATION

Position of the patient

The patient should be supine without the aid of any sandbags or splinting of the leg. This permits synchronous harvesting of the flap with the head and neck resection. Though not essential, ideally all monitoring lines should be placed in the other leg.

Incision

The incision is placed along a line drawn between anterior superior iliac spine and the lateral border of the patella (Figure 25.2) unless it crosses where a perforator can be heard on the Doppler (in which case the line should be moved to give at least 1 cm clear skin between the signal and the flap margin). If a sensate flap is required, the lateral femoral cutaneous nerve can be harvested. Conveniently, this runs along the line joining the anterior superior iliac spine to the lateral border of the patella and is found to lie in the deep subcutaneous tissue just above the fascia. No further flap marking is carried out to permit relocation when the perforator(s) are visualized much later. The incision should be angled at 45° laterally to protect any nearby perforator(s) and is deepened to incise the deep fascia to expose the underlying rectus femoris or vastus lateralis muscle. Though the pedicle is short it may still be useful. The transverse branch of the lateral circumflex femoral artery gives rise to perforators to form the tensor fascia lata flap. The pedicle is situated at the superior end of the line joining the anterior superior iliac spine to the lateral border of the patella and lies between the tensor fascia lata and rectus femoris muscle. Perforators may be located in a similar fashion by dissecting below the fascia in a medial to lateral direction. Again this will tend to offer a bulky flap with a shorter pedicle than the anterolateral thigh flap.

It is recommended to first trace out the perforators by careful dissection to the main pedicle rather than dissect them out completely as the latter manoeuvre is more easily performed once the entire pedicle can be visualized. Side branches from the perforators should be coagulated with a bipolar diathermy or ligated with small metal clips, particularly if close to the perforator. Perforators are followed through muscle and/or fascia until the main pedicle (descending branch of the lateral circumflex femoral artery) is reached within the groove between rectus femoris and vastus lateralis muscles.

It is not recommended to locate the descending branch of the lateral circumflex femoral artery by dissecting down into the groove between the rectus femoris and vastus lateralis and then follow branching lateral perforators in a lateral direction towards the skin, as most of these perforators will end in muscle.

Muscular component

Starting medial to the descending branch of the lateral circumflex artery, in a lateral direction a sheet of vastus lateralis muscle can be raised. The muscle is usually 1.5–2.5 cm thick and 6–10 cm in width. Although sheets of muscle greater than 10 cm in length almost inevitably have at least one perforator smaller lengths of muscle can be raised by identifying muscular perforators coming of laterally from the pedicle into the muscle. The muscle sheet can be dissected with the skin paddle on top or more distally (Figure 25.4).

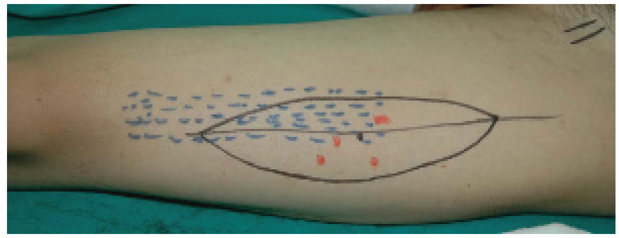

Figure 25.4 Picture shows the anterolateral thigh (ALT) flap muscle marked out more distally than skin. The muscle paddle can be raised like this or coincident with the skin paddle depending on where the two tissues are required.

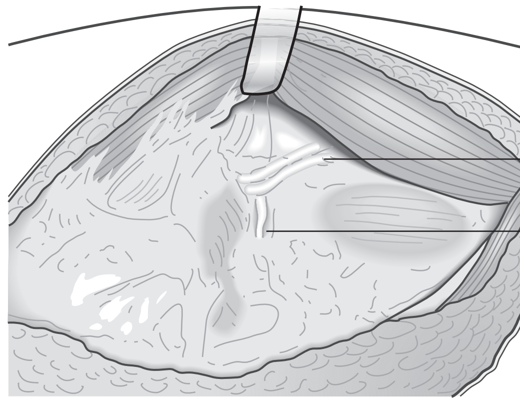

Figure 25.5 Exposure of the pedicle: descending superficial circumflex femoral artery and vena comitantes with perforator in the foreground.

Pedicle dissection

The artery and its venae comitantes are followed from the junction with the perforator(s) to the junction with the profunda femoris artery and vein if the entire length of the pedicle is required (Figure 25.5). During this dissection, it is helpful to self-retain the muscle by placing large sutures from its underbelly to the lateral skin. Once the junction has been identified, the full dissecting out of the pedicle and perforators can take place in a proximal to distal direction. If the entire length is not required then it is not necessary to dissect out the entire descending lateral circumflex vessel, however, the artery and venae comitantes may be much smaller (at around 2 mm) before both transverse and ascending vessels join so it may be preferable to accommodate a lengthy pedicle in the neck rather than have an ideal length with small vessels. During this dissection many branching arteries and veins will be encountered and will require ligation. This may include the ascending and transverse lateral circumflex vessels (Figure 25.6). Branches of the femoral nerve run underneath the pedicle and will have to be dissected out carefully. This becomes more problematic as the diameter of both the pedicle and nerves become smaller, and it may be preferable to sacrifice a small nerve branch which will have little, if any, impact on motor function rather than

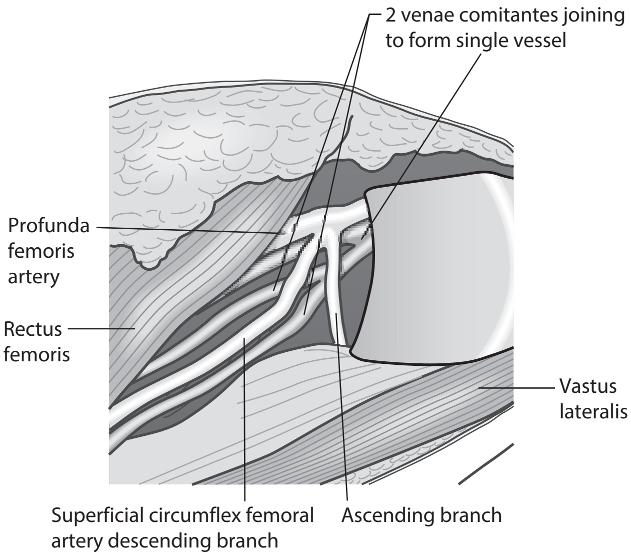

Figure 25.6 Junction of pedicle and profunda vessels.

damage the pedicle or perforator(s). During the dissection of the musculocutaneous perforators, by leaving a 5 mm cuff of muscle around these perforators, the dissection is made less hazardous and the perforators are made more robust.

Flap design and skin paddle elevation

Once the main pedicle and perforator(s) have been fully dissected out, the skin flap can now be designed. If two perforators are present then, unless the flap is very large, it will encompass both ends of its length. If there is just one perforator or there are two and the surgeon has a specific requirement, the position of the paddle can be varied according to need. The further down the thigh, the thinner the tissue becomes (Figure 25.7), but if it is planned to anastomose at the large termination part of the pedicle this will produce a very long pedicle.

According to some authors, flap thickness in Caucasians is 4 cm in the upper thigh, 3 cm in the mid-thigh and 2 cm in the lower thigh. The tissue is much thicker as a result of fat deposition in the superior thigh, but the pedicle is often an ideal or manageable length for most oral reconstructions and the increased bulk may be desirable. A compromise may be reached to end up with a slightly thicker flap than necessary, with a slight pedicle length excess but with very large vessels to use in an anastomosis.

To ensure that the ‘backcut’ flap incision does not violate the perforator(s) it is recommended to pass a small needle from the fascia towards and out of the skin at a point situated a minimum of 1 cm from the pedicle below the fascia where the perforators can be visualized. The flap can then be marked around this, and the flap raised and isolated from all but its blood supply to permit evaluation of the viability of the flap.

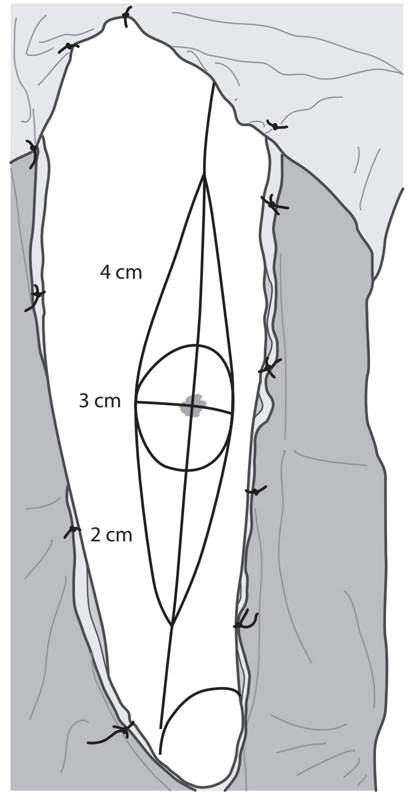

Figure 25.7 Flap thickness at different thigh levels.

Observing the undivided flap

There should be clear evidence of bleeding subcutaneous flap tissue at this time. If two perforators have been raised, the viability of either perforator can be assessed using a microvascular clamp on the pedicles (Figure 25.8).

This manoeuvre is essential if the flap is to be divided and used as two separate or chimeric flaps. During the interval between the completed elevation of the flap and pedicle division, the flap should be sutured to one of the wound margins with the pedicle under no tension. This will prevent the flap accidentally falling off the leg downwards, which might produce a force sufficient to tear the pedicle.

Dividing the flap

This is straightforward and the same as for any other flap, the vessels in the thigh should be transfixed if harvesting at the profunda junction. The flap should be irrigated with heparinized saline. If clotted blood becomes dry in the perforators, it will be difficult to get them running again. If there is only one perforator before the pedicle is divided, a stitch should be run from part of the perforator (preferably the muscle) cuff to a flap margin to prevent torsion or kinking of the perforator.

Closure of the donor site

This can be commenced as soon as the flap has been completely raised and a large part of the closure can be carried

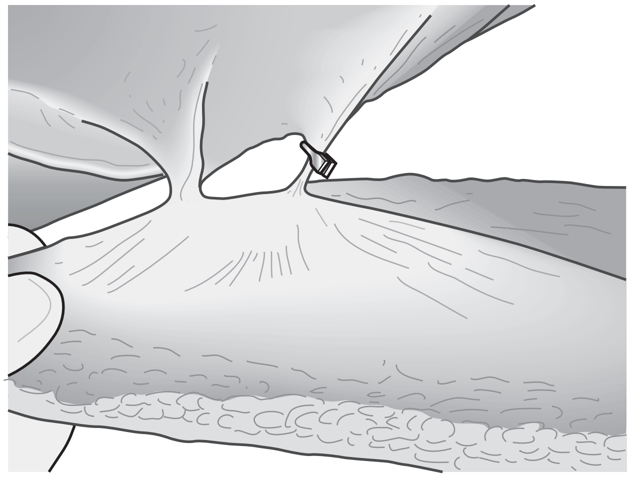

Figure 25.8 Flap with microvascular clamp to assess flow of unclamped perforator.

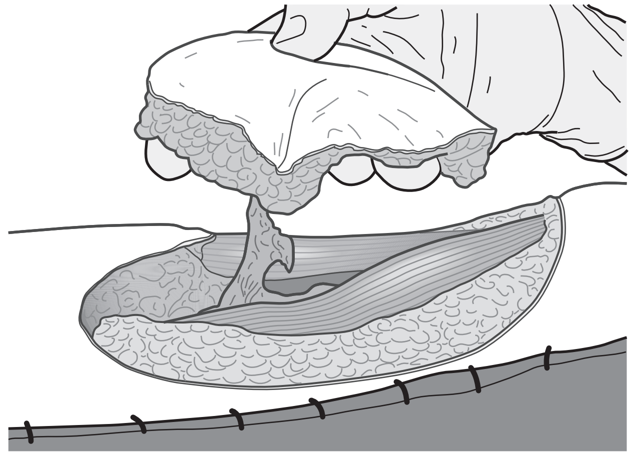

Figure 25.9 Bulky anterolateral thigh flap.

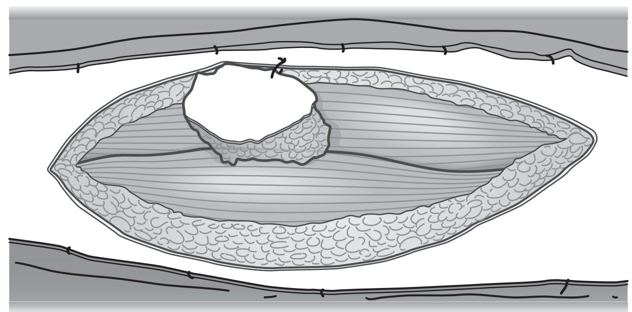

Figure 25.10 Flap temporarily attached to skin.

out prior to pedicle division. If closure is not to be carried out immediately, three sutures (2/0 or larger) should be used to close the donor site temporarily, as swelling will otherwise make closure very difficult.

After diathermizing any bleeding points, closure should commence with repair of any muscle that has been divided to permit perforator dissection. A resorbable 3/0 stitch is recommended. Closure of the fascia and subcutaneous tissue should then be carried out using a 2/0 resorbable suture. If the pedicle has not been divided, the superior part of the wound can be left open, to be closed after pedicle division. The skin can be closed with either non-resorbable sutures or clips. It is not recommended to insert a drain in the leg, although a tight crepe bandage is desirable. Flaps of up to 10 cm width can be closed primarily but nylon tension sutures will probably have to be used to achieve this. A very pleasing cosmetic result can be expected after the skin has healed (Figure 25.16)

Insetting the flap

Flap insetting may be made difficult if it is too bulky for the defect (Figure 25.9). Certainly trimming the fat, particularly at the margins of the flap, is helpful in this scenario. If the flap is tight as it is inset, it is recommended to orientate it with a minimum number of sutures (say four) and then proceed to anastomosis (Figure 25.10). The flap is then allowed to run before insetting. If the flap is to be tubed, the deep fascia can be closed around the skin layer as a double closure.

POST-OPERATIVE CARE

Monitoring the flap

The skin is easily monitored and a Doppler probe can be placed on the site of the perforator in the flap as before it was raised; this is easily achieved for flaps used for skin replacement but more problematic for intraoral flaps, although this is easier with a detachable internal monitoring probe. Otherwise, monitoring the pedicle in the neck is usually adequate. If the blood flow is to be evaluated using a needle prick, blood flow may be slower than that seen in other flaps. After radiotherapy or at least 1 month, the flap can be safely thinned if it is too bulky.

COMPLICATIONS

Intraoperative

Damage to the fine perforators is the obvious and catastrophic complication. Fortunately, this is most likely to occur in the very early stages of the flap, when it can be abandoned for an alternative. Where there are two perforators (Figure 25.11) twisting is not a problem but twisting a single perforator is a hazard that should be avoidable by placing the safety stitch (Figure 25.12) as described in the section 'Complications intraoperative'.

Post-operative

In the author's experience, this is an extremely reliable flap (Figures 25.13 through 25.15), but vigilance for arterial and venous failure is clearly essential. Even partial flap necrosis is rare. Gait problems may require months to resolve if a large number of femoral nerve branches have been sacrificed. Thigh numbness may result, but is likely to be of little significance to the patient.

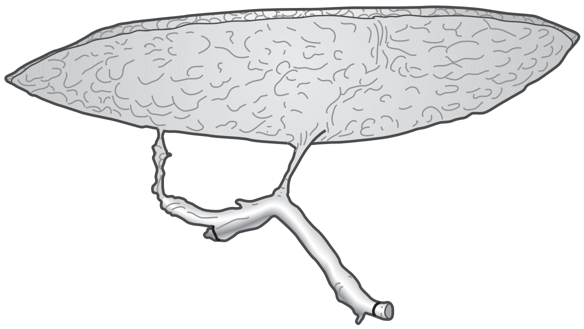

Figure 25.11 Detached flap with two perforators.

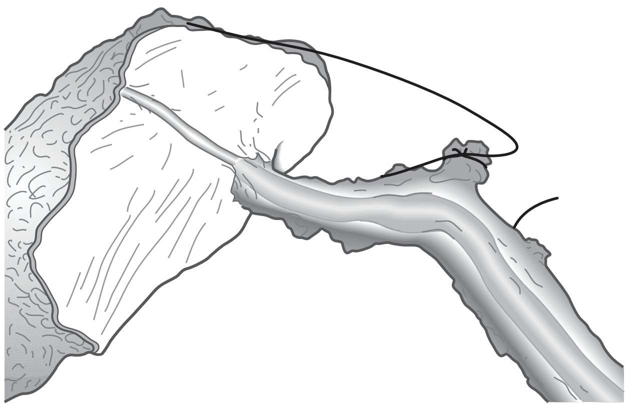

Figure 25.12 Detached with single perforator and anti-twisting stitch.

Figure 25.13 Anterolateral thigh flap used on scalp.

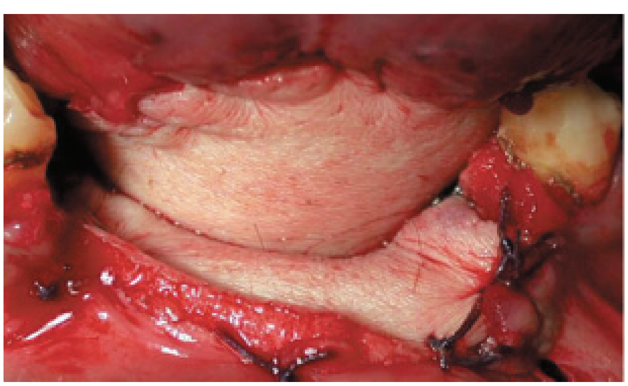

Figure 25.14 Anterolateral thigh flap used for floor of mouth reconstruction.

Figure 25.15 Anterolateral thigh flap used for parotid area reconstruction.

Figure 25.16 Donor site after six months.

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26

Gracilis flap

HENNING SCHLIEPHAKE

CONTENTS

RECONSTRUCTIVE USE

The gracilis flap is most frequently used in free neuromuscular tissue transfer for facial reanimation after longstanding facial paralysis. The low profile of the muscle and the organization in small innervated segments make this flap particularly suitable for the reconstruction of mimic muscles. Gracilis muscle free flaps are, however, also used as innervated muscle segments for tongue reconstruction and for skull base repair as muscle-only flaps. The skin overlying the muscle has been reported to be unreliable, but myocutaneous gracilis free flaps have been successfully transferred as transverse upper gracilis (TUG) flaps for breast reconstruction.[1,6] Moreover, the muscle is extensively used as a pedicled flap for reconstructive procedures in the perineal area.

ANATOMY

The gracilis muscle is a flat and thin adductor muscle of the thigh. It originates from the ramus of the pubic bone and inserts at the medial tibial tuberosity below the knee. The gracilis muscle is a type II muscle according to the classification of Mathes and Nahai with its dominant vascular supply arising from the adductor artery and vein which branch off of the profunda femoris artery and vein. The vascular pedicle commonly has two comitans veins and enters the gracilis muscle 8–10 cm distal to the pubic tubercle. Minor vascular pedicles arise from the superficial femoral artery (distal) and the medial circumflex artery (proximal). The motor nerve supply comes through the anterior branch of the obturator nerve and enters the muscle approximately 2 cm proximal to the vascular pedicle.

OPERATION

Position of the patient

The patient is positioned supine with the hip of his donor leg flexed, abducted and rotated outwards and his knee moderately flexed so that the foot rests on the operation table at the height of the opposite lower leg (Figure 26.1). This position is secured by support against the calf and the thigh, preventing the knee from stretching and thigh from rotating backwards and inwards. Care must be taken to provide adequate padding for the calf in order to prevent pressure ulcers on the skin overlying the tibia. The leg and the pubic hair should be shaved preoperatively, and the site should be draped in a way that the inner half of the thigh and the landmarks (medial tibial tuberosity and the pubic tubercle) are exposed and can be clearly palpated. The surgeon is positioned on the side of the operation table opposite to the donor leg.

Skin incision

A straight line is drawn between the pubic tubercle and the tibial tuberosity. In an upright position, this would delineate the anterior margin of the gracilis muscle. In a horizontal position in relaxation, the muscle drops down and the anterior margin is located approximately 15 mm posterior to the straight line, where it should be marked with an additional line. The incision through the skin and subcutaneous fat tissue is carried out along this line approximately 20 cm in length starting below the pubic tubercle. The incision goes through the superficial fascia down to the fascia lata.

Exposure of the gracilis muscle

The gracilis muscle midbelly is identified after incision of the overlying fascia and clearly distinguished from the sartorius muscle, which is located anterior to the gracilis in the surgical position of the leg in the mid thigh, and from the adductor longus muscle that is located immediately anterior to the gracilis muscle in the proximal thigh (Figure 26.2). Separation of the skin and the subcutaneous fat tissue from the lateral aspect of the muscle can help to identify the gracilis from the small anterior–posterior dimension. The intermuscular septum between the adductor longus and the gracilis muscle is carefully divided superficially, and small vessels that may enter the anterior margin of the muscle can be coagulated and divided.

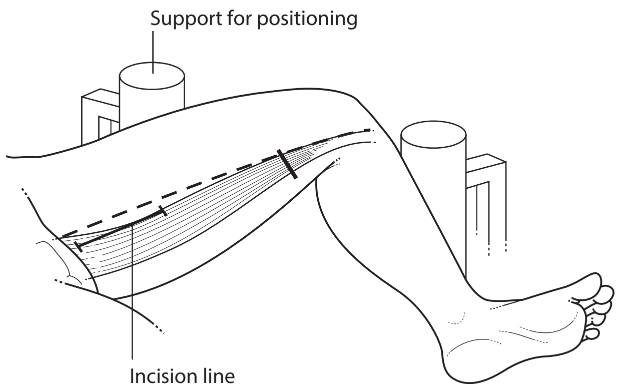

Figure 26.1 Positioning of the donor leg.

Identification of the vascular pedicle and the motor nerve supply

The vascular pedicle runs in the intermuscular septum between the adductor longus and the adductor magnus before entering the gracilis muscle (Figure 26.3). It is first identified when carefully dividing the adductor longus from the gracilis muscle at the anterior margin of the gracilis by blunt dissection whilst reflecting the gracilis muscle. In this position the vessels are running across the surface of the adductor magnus muscle that becomes visible between the adductor longus and the gracilis muscle (Figure 26.4). After identification of the artery and the two comitans veins, the motor nerve supply is dissected and exposed by continuing the dissection slightly more proximal, where the anterior obturator nerve can be identified from its oblique course across the surface of the adductor magnus muscle. The nerve enters the gracilis muscle approximately 20 mm proximal to the entry of the vascular pedicle.

Dissection of the vascular pedicle

Before entering the gracilis muscle, the vascular pedicle gives off small branches to the adductor longus muscle (Figure 26.3). These branches have to be ligated to get access to the full pedicle length. During this procedure it is helpful to pull up the adductor longus muscle with two small retractors placed proximally and distally to the vascular pedicle. Fine scissors and forceps are necessary to accomplish blunt release of the tiny branches from the adductor longus muscle surface. After elevation of the branches, haemostat clips are used for ligation. Electrocautery of the

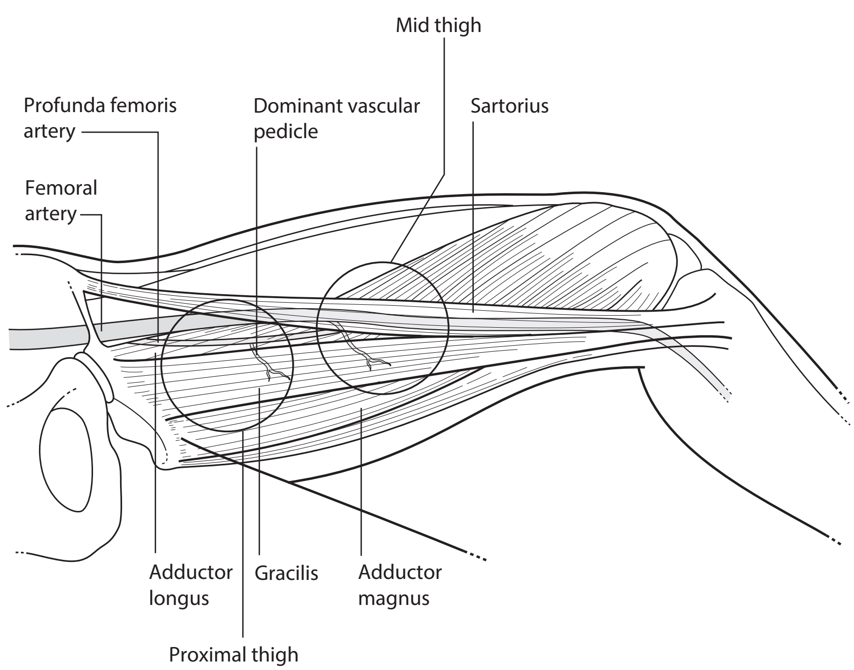

Figure 26.2 Spatial relationship of the gracilis muscle at mid thigh and proximal thigh.

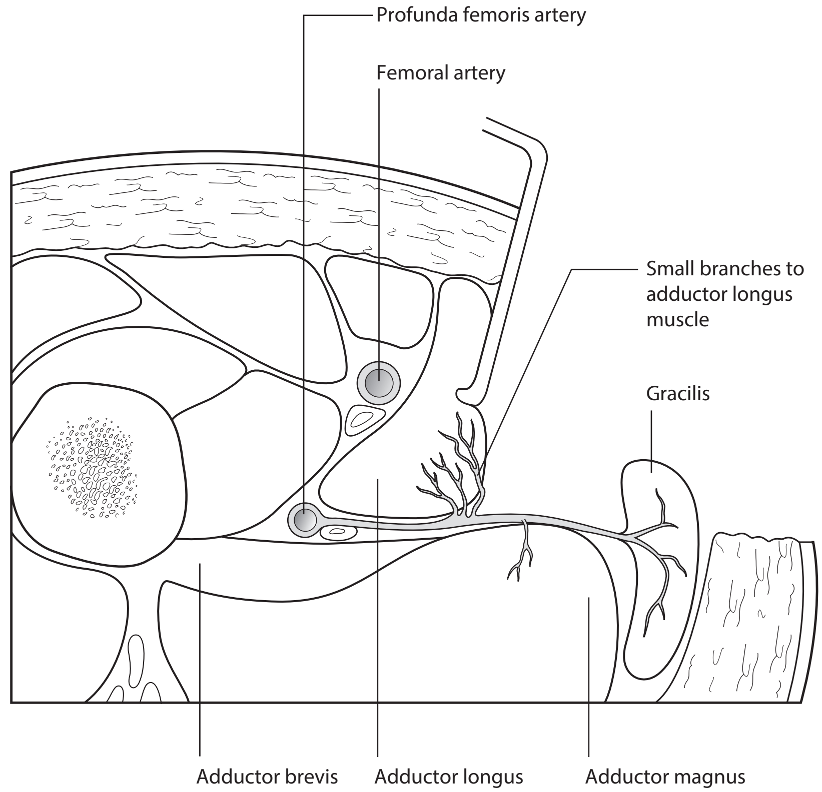

Figure 26.3 Anatomy of the course of the vascular pedicle.

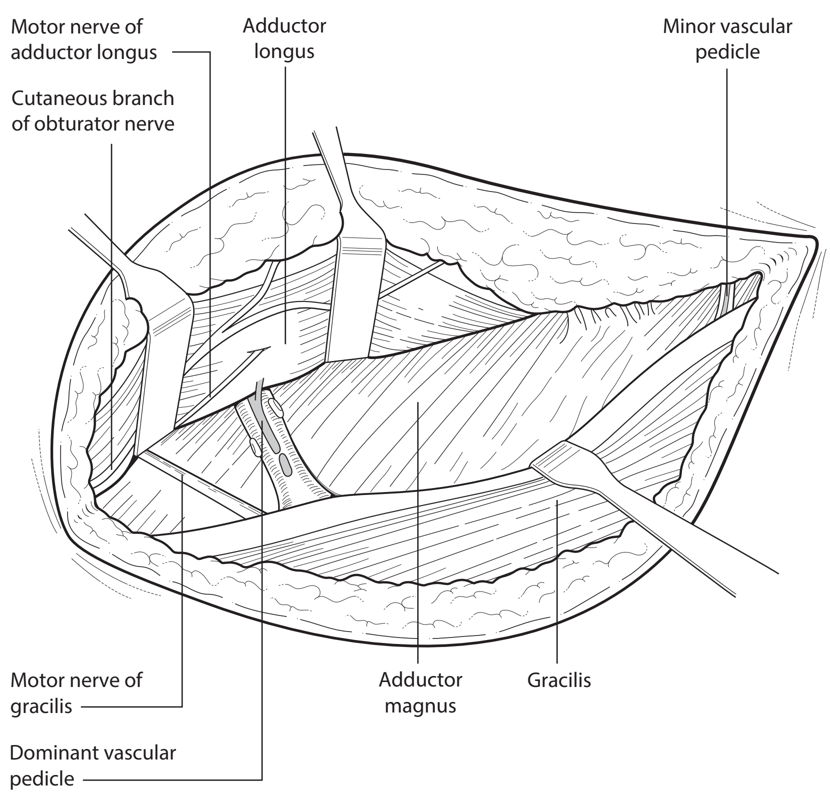

Figure 26.4 Identification of the vascular pedicle between adductor longus and gracilis, lying on the adductor magnus.

small vessels is not recommended in order to avoid thermal damage to the main pedicle. After separation of the branches, the adductor longus muscle can be pulled fully upwards giving way to the dissection along the pedicle to the profunda femoris vessels (Figure 26.5). There may as well be branches that run off into the underlying adductor magnus muscle. They have to be identified and ligated by carefully elevating the vascular pedicle from the muscle surface before the pedicle is separated from the profunda femoris vessels. During ligation of the pedicle, care must be taken not to compromise blood flow in the profunda femoris vessels. Therefore, a minimum distance of 5 mm from the junction between the pedicle and the profunda femoris artery and vein should be observed when the pedicle is cut. After completion of the dissection of the adductor artery and vein, a pedicle length of approximately 6 cm should be available. The diameter of the vessels can be expected to be between 2 and 2.5 mm on average.

Dissection of the obturator nerve and definition of the graft size

The obturator nerve that has been previously identified is easily followed along its course proximally by blunt dissection until a length of approximately 8 cm is achieved. A nerve stimulator is used to define neuromuscular units. If very small muscle segments are planned, dissection of the nerve under the microscope can be carried out, and individual neuromuscular units can be identified after stimulation of individual fascicles (Figure 26.6). The nerve usually contains three fascicles although there may be up to seven present. The anterior half of the muscle belly is commonly innervated by one fascicle; the posterior half is supplied by the remaining ones with some overlap in the midline. The width of the muscle segment that is used for facial reanimation commonly occupies half of the width of the muscle belly, so that the anterior half of the muscle is divided for harvesting (Figure 26.7). In the proximal half, the muscle fibres run parallel which makes division in a longitudinal direction easy. The length of the muscle required has to be identified beforehand during preoperative planning and the dissection of the recipient site in the cheek (see Chapter 29). Usually a length of approximately 8 cm is needed. To avoid inadvertent damage to the neurovascular pedicle during release and circumcision of the deeper muscle portions a small retractor is inserted underneath the pedicle close to its entry into the muscle and gently pulled upwards. During final separation and mobilization, the epimysium is preserved on the surface of

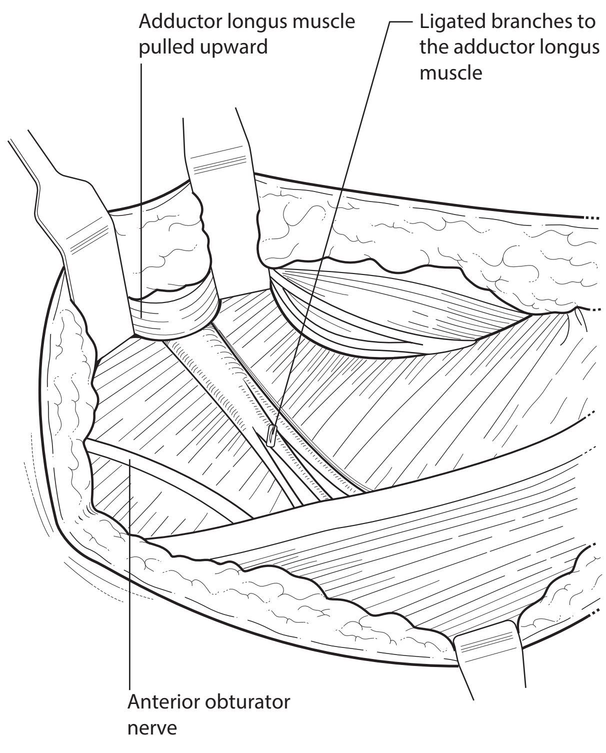

Figure 26.5 Complete exposure of the vascular pedicle and nerve supply.

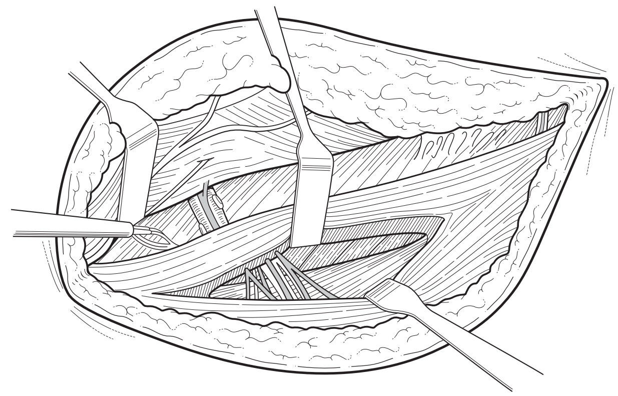

Figure 26.6 Dissection of the muscle to identify individual muscular units.

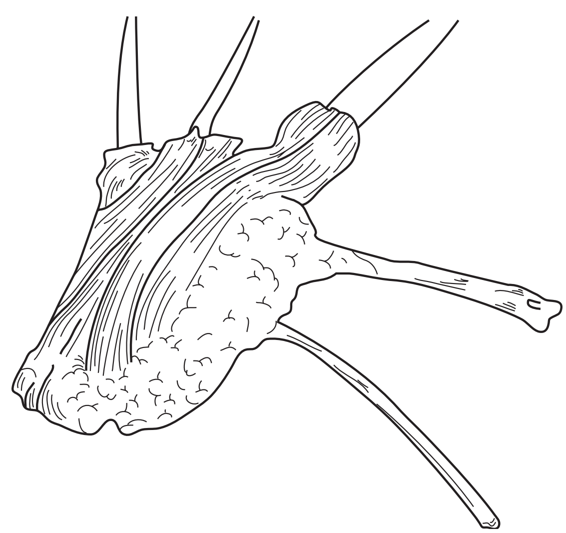

Figure 26.7 Division of the proximal graft end to suit the lips and the oral commissure.

the muscle to provide a sliding layer for easier movement of the muscle during contraction after transfer. Before the pedicle is divided, adequate perfusion of the muscle segment is checked.

After complete separation, the function of the obturator nerve segment included in the graft should also be checked with the nerve stimulator after placing the graft on a moist surgical towel on the patient. The graft is then stored in moist surgical towels until definite graft fixation and microvascular anastomosis are performed.

Wound closure and postoperative care

Meticulous control of bleeding from the trans-sectioned muscle tissue is performed by electrocautery. The anterior margin of the remaining parts of the gracilis muscle is attached to the fascia of the adductor longus muscle to stabilize the gracilis muscle and restore easy function of the adductor muscles. A 10-gauge suction drainage is placed on the reconstructed fascia, and the wound is closed in layers. The leg is bandaged with decreasing pressure from distal to proximal, or a pressure stocking is applied to avoid postoperative thrombosis.

Routine postoperative prevention of thrombosis is applied by administration of fractionated heparin (e.g., enoxaparin). The operated leg should be positioned in a slightly elevated position for a couple of days until complete mobilization of the patient is achieved. Postoperative mobilization with the help of a physical therapist can be performed from the first postoperative day as the muscle function of the adductor group remains grossly unaffected by the removal of the small gracilis segment and its nerve supply. If no substantial bleeding occurs, the suction drainage can be removed on the second postoperative day.

COMPLICATIONS

In general, harvesting of the gracilis muscle has very low morbidity, and complications are rarely encountered associated with this procedure.

Intraoperative complications

- Damage to the pedicle may occur during the release of the branches to the adductor longus and adductor magnus muscles. The use of the microscope during dissection and the use of clips rather than electrocautery during ligation are helpful in avoiding this problem.
- Damage to the profunda femoris vessels may occur during separation and ligation of the pedicle. In particular, the profunda femoris veins are prone to compromised blood flow and subsequent thrombosis. This can be avoided by observing an adequate distance of 5 mm pedicle length during ligation and separation of the pedicle from the profunda femoris vessels and by using clips rather than sutures for ligation.
- Nerve damage is unlikely to occur as the dissected segment of the obturator nerve is short and interference with other nerves is not encountered.

Postoperative complications

- Haemorrhage: Postoperative bleeding is unlikely to occur as the site of harvest does not contain high-volume flow vessels, and the dissection is carried out only along intermuscular septa without dividing or cutting vessels with relevant blood flow that could be violated inadvertently and overlooked during wound closure. Nevertheless, improperly seated ligation clips after separation of the pedicle from the profunda femoris vessels can become detached and cause substantial haemorrhage. Thus, great care is required during this step of the dissection to make sure that ligations of the adductor vessels are reliable.
- Secondary bleeding from the transected muscle may occur if haemostasis has been inadequate. The careful use of electrocautery after identification of individual intramuscular branches under the microscope before wound closure minimizes this risk.
- Thrombosis: Thrombosis is also unlikely to occur if routine heparin prophylaxis is administered and early mobilization is accomplished. The saphenous vein that drains the superficial venous system is located above the site of harvest. This vein is commonly not encountered during dissection and thus can be easily preserved. Deep venous thrombosis may occur if ligation clips or sutures compromise the blood flow in the profunda femoris veins, which can be avoided by observing an adequate distance to the vein during ligation as described above.

Top tips

The dissection of the flap is very straightforward, with little chances to go grossly wrong. Nevertheless, a few things can ease the surgical work and improve the results.

- During flap dissection, the division of the branches that go off into the adductor longus is a crucial point. Use high magnification to make sure that this is done carefully, and take your time. Use clips or microcautery.
- As the pedicle is rather short, use as much length as you can get; however, keep in mind to preserve a 5-mm cuff for ligation to avoid thrombosis of the femoris profunda vein.
- When defining the muscle volume, take care not to obtain too much tissue. Careful nerve testing and definition of functional muscle units will improve the result in terms of cosmetics, as unsightly bulging of the grafted muscle during contraction is avoided. Trimming of the muscle after transfer is always more difficult and carries the risk of removing the wrong muscle units.

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27

Fibular flap

PETER A BRENNAN and MARK SINGH

CONTENTS

INTRODUCTION

The fibula is a long slender triangular-shaped bone that is said to have two functions: ankle joint stability and microvascular reconstruction of bony defects. It is mainly composed of cortical bone, giving it great stability. The advantages of the fibula are that it offers an abundant supply of tubed bi-cortical bone, which is useful for reconstruction of long segmental defects across the midline – 25 cm or more of bone can be harvested. There is usually little morbidity at the donor site, and it is highly reliable with a 95% success rate (when used, the skin paddle component is reported to be less reliable). It is also possible to harvest the fibula simultaneously with the tumour resection as no change in the patient's position is required. Bone height is the main potential disadvantage, especially when reconstructing the dentate mandible. To overcome this problem, the osteotomized fibula can be folded back onto itself whilst maintaining intact soft tissue and periosteum on one side ('double barrelling'). Distraction osteogenesis, followed by implant placement, can also give a very good result (Figure 27.1). It is usual to leave the flap for several months before distraction, to allow bony union with the recipient bed and enable the fixation plates to be removed.

HISTORICAL DEVELOPMENT

The first vascularized fibula flap transfer was used for ulnar reconstruction by Ueba in 1974 (series of cases published in 1983).[1] Taylor et al. subsequently reported free fibula transfer for two tibial defects in 1975.[2] As the flap was increasingly used, modifications were made, such as including large parts of the soleus muscle and skin paddles. Although these first fibula transfers were performed without a skin paddle, Chen and Yan were the first to report an osteo-cutaneous fibula flap in 1983.[3] Hidalgo reported the use of the vascularized fibula in mandibular reconstruction in 1989, and this opened a new field in maxillofacial reconstructive surgery.[4]

The fibula is the longest bone flap available, and it can be transferred as a bone flap or in combination with a skin island for soft tissue coverage if required. Therefore it has a broad spectrum of indications ranging from bony reconstruction of the extremities to partial or total mandibular reconstruction including closure of perforating defects of the oral cavity. The disadvantage of the skin paddle is that it cannot be rotated separately from the bone (as compared to a scapula flap).

SURGICAL ANATOMY

An understanding of the relevant anatomy of the fibula and the arrangement of muscles, compartments and vascular supply of the lower limb below the knee is vital (Figure 27.2).

The lateral compartment of the lower leg (lateral to the fibula) is formed by peroneus longus and brevis muscles (the latter muscle arising from the fibula more distally). In the anterior compartment, extensor hallucis longus (EHL) and

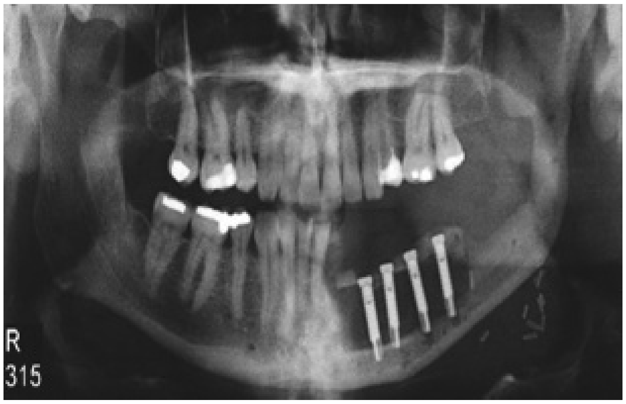

Figure 27.1 Implants placed in a recently distracted fibula.

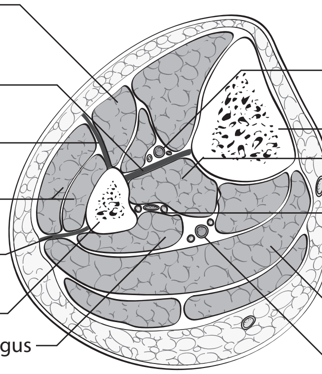

Figure 27.2 Cross-section of the mid calf. The inter-osseous membrane and anterior/posterior crural septae have been highlighted in bold (nerves have not been shown).

extensor digitorum longus are attached to the anterior surface of the fibula. The large tibialis anterior muscle is found near the tibia. Separating the anterior and posterior compartments is the anterior inter-osseus membrane – a white fibrous band that is attached to both fibula and tibia. The anterior tibial artery and deep tibial nerve can be found running close to this membrane. In the posterior compartment, lying between tibialis posterior and flexor hallucis longus (FHL) muscles (and close to the deep surface of the fibula) are the peroneal vessels. The soleus and gastrocnemius form the muscle bulk of the posterior compartment. Finally, the anterior crural septum runs between peroneus longus and brevis and EHL, whereas the posterior crural septum runs between the peroneus longus and FHL – the latter septum is usually used to reach the fibula during the dissection.

VASCULAR ANATOMY

- The fibula is supplied by periosteal branches of the peroneal artery, and by an endosteal vessel which directly enters the bone at the middle third/distal third junction.[5] The peroneal artery arises from the posterior tibial artery, and runs between the chevron-shaped fibres of tibialis posterior and FHL, running close to the fibula, along its deep surface. The vascular pedicle is relatively short (approximately 6 cm), but it can be made longer by harvesting the fibula more proximally than that required for the reconstruction – following detachment of the flap, the pedicle is dissected free from this excess bone, which is subsequently discarded.
- Between two and six cutaneous perforator vessels emerge from the peroneal artery. They pass posterior to the fibula and may be myocutaneous (perforating FHL and/or soleus) or septocutaneous. A paddle of skin can be harvested with the main bone flap. There is anatomical variation in location, course, size and number of these cutaneous perforators according to anatomical studies and various clinical reports. Different survival rates of the skin island have been reported and various proposals have been made to improve its reliability. Yu et al.[6] performed a live study on 80 consecutive fibula flaps looking at perforator patterns. They found two discrete groups of perforators located proximally and distally. If the fibula was divided into quarters, the clinically useful perforators (distal) were located over the third quarter. In 51% of cases, there were two or more perforators approximately 1.5 cm posterior to the line connecting the fibula head to the lateral malleolus. Surprisingly, they also found that over 90% of the perforators were septocutaneous. The most reliable region for harvesting the skin paddle was found to be 8–12 cm above the ankle – an area corresponding to the third quarter of the fibula.[6] To facilitate identification of the cutaneous perforators, pre-operative mapping using a handheld Doppler probe is advisable. The perforators can also be seen on pre-operative imaging.
- There are a number of important anatomical variations of the lower limb arterial supply, which need to be known (Figure 27.3). The normal arterial supply is found in 88%. Although some information can be obtained by a standard vascular examination and duplex assessment, accurate assessment of the patient's lower limb vasculature can only be provided by conventional angiography or magnetic resonance angiography (MRA). The latter is becoming widely used, especially because it avoids arterial puncture and its associated complications.[7] In the authors' opinion, such vascular assessment is mandatory before harvesting a fibula flap to exclude congenital peroneal artery anomalies. These include a dominant peroneal artery (0.2% of patients) or congenital absence of the peroneal vessels (less than 0.1%). Because many of these congenital and acquired peroneal artery anomalies are unilateral, it is advisable to obtain bilateral leg imaging before harvesting a fibula flap. Both of the authors have encountered a variation of the abnormally long tibio-peroneal trunk. In one case, the peroneal artery joined the fibula some 26 cm from the fibula head (Figure 27.4).[8] However, not all surgeons routinely request these tests, with some relying instead on duplex scanning alone.[9]

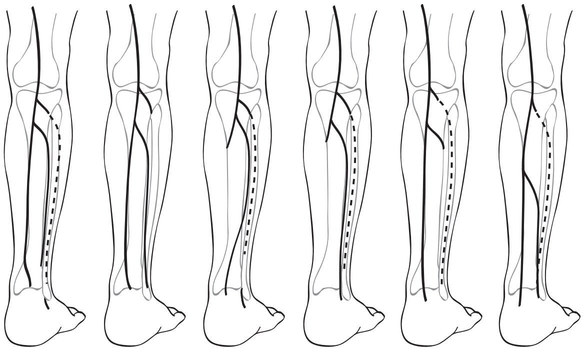

Figure 27.3 Anatomical variations of the lower limb arterial supply.

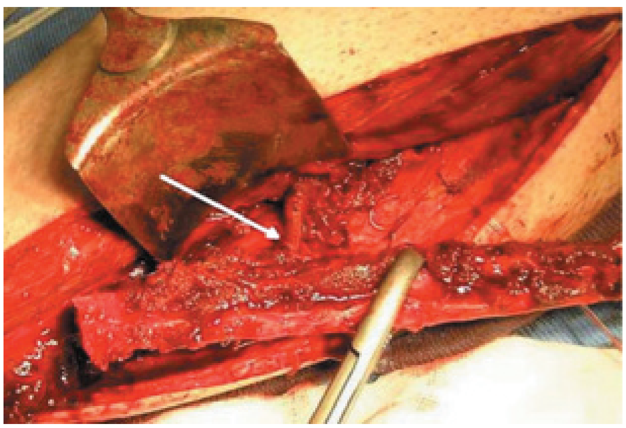

Figure 27.4 Anatomical variant with peroneal artery joining fibula some 26 cm below the fibula head.

- It should be noted that in the authors' experience there can be a discrepancy in the length of the pedicle depending on which leg is chosen. This is due to variations in the length of the tibio-peroneal trunk. This is shown in Figure 27.5 where the right lower limb has a shorter tibio-peroneal trunk giving almost 5 cm longer pedicle.
- Peripheral vascular disease occurs quite frequently in head and neck cancer patients, and the peroneal artery typically serves as an important collateral blood supply to the foot. Clearly, if there is significant atheroma in the lower limb vessels, and/or an anatomical variant with one or more vessels missing, it is better not to carry out a fibula free flap. Foot loss following this procedure has been reported in the literature!

CLINICAL USE OF FIBULA FLAP IN MAXILLOFACIAL SURGERY

In maxillofacial surgery, the fibula flap is mainly used for primary or secondary reconstruction of extensive

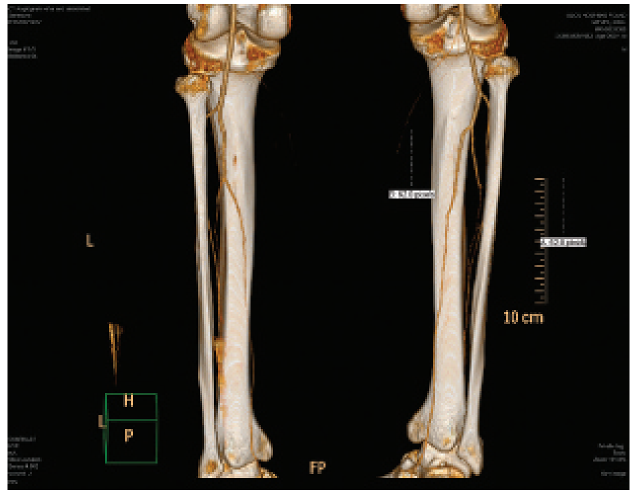

Figure 27.5 Computed tomography angiogram showing the longer tibio-peroneal trunk on the left side, resulting in a shorter pedicle length.

mandibular bone defects. When greater depth of bone is required in large mandibular defects, it may be possible to fold the bone back on itself (double barreling), or perform interval distraction osteogenesis. The flap can also be used for congenital malformations, and some have recommended its use in pre-prosthetic surgery. It has many other uses outside the head and neck region.

It should be mentioned that the fibula anatomy can allow us to raise solely a soft tissue flap based on the same pedicle. This can be very useful especially if one wants to avoid the complications concerning the donor site of the radial forearm. The anterolateral thigh flap has been suggested as an alternative to the radial forearm flap, but this can be difficult if the patient is not thin and can lead to quite a bulky flap. Wolff et al. published their series of 30 peroneal perforator flaps which details the procedure.[10]

PLANNING

With the advent of computer-assisted design and computer-assisted manufacture (CAD–CAM) technology and rapid prototyping modelling (RPM), surgical planning for fibula flaps has evolved to a very precise procedure. The advantages have been well documented to improve outcomes and save operative time (Figure 27.6).

Manufacture of three-dimensional (3D) models allows the ablative surgeon, with the assistance of the maxillofacial technician, to perform model surgery to assess the shape and size of the defect. This then gives the surgeon a chance to plan for complex shapes such as a mandibular resection involving body, angle and ramus or the anterior mandible (Figures 27.7 and 27.8). Knowing the shape of the defect allows for reconstructive plates to be pre-bent, which saves time at operation and improves accuracy at restoring form. The plates can be made with locators so as to reproduce their placement from the lab

Figure 27.6 Computer-assisted design and computer-assisted manufacture model with pre-bent plate.

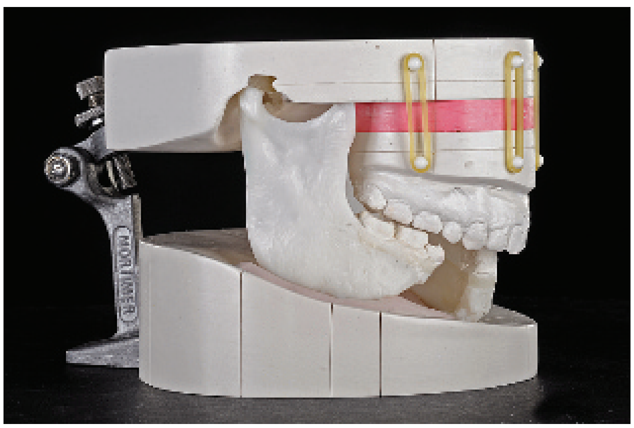

Figure 27.7 Articulated three-dimensional model of mandible and maxilla.

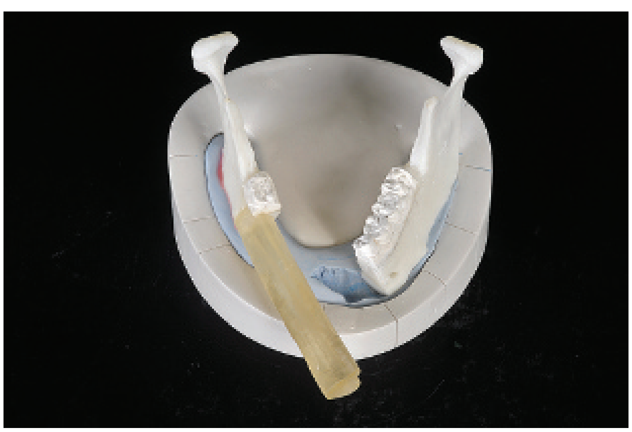

Figure 27.8 Assessment of location of osteotomy cuts required to correctly shape the fibula (clear acrylic).

to the theatre. Maintaining spatial relationships ensures improved outcomes.

From a reconstructive point of view, the same technology can be used to reproduce the donor fibula. The fibula

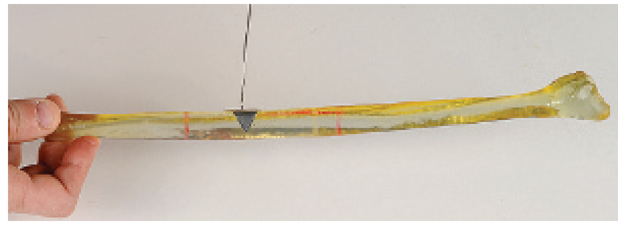

Figure 27.9 Intraoperative cutting guide (metal locator fits on fibula) with angle of cut.

can then be assessed for the quality of bone to help produce stents to guide osteotomy cuts and even implant placement (Figure 27.9).

SURGICAL TECHNIQUE

The fully anaesthetized patient is placed on their back, and the leg is flexed at both the hip and knee joint and brought into a prone position for better access to the lateral and posterior aspect of the calf. We have described a simple triangular-shaped padded device that when placed under the knee, greatly facilitates this position.[11] It can be easily constructed by a competent dental technician as follows:

1. The entire lower extremity is prepared with antiseptic solution, and the foot is enclosed in a sterile drape. Both authors do not routinely use a tourniquet for flap harvest. If a tourniquet is preferred, this should be inflated to over 300 mmHg, and should be released after a maximum of 2 hours to prevent re-perfusion injury. The fibula head and lateral malleolus (as constant anatomical landmarks) are identified and marked. A line drawn between the two is the surface marking of the posterior inter-crural septum (one of the approaches to the lateral fibula – the other being via the anterior crural septum).
2. For a bone-only fibula graft, a skin incision is made along this line, in the middle to distal one-third of the palpable bone. Superiorly, the incision should not pass too close to the fibula head, for risk of subsequent damage to the common peroneal nerve. Inferiorly, at least 6–7 cm of bone should be left to maintain ankle joint stability (Figure 27.10). When a skin paddle is required, the initial linear incision can be modified and placed more anteriorly than the line marked in Step 1. Once the skin flaps have been raised and the perforator(s) identified emerging from the posterior surface of the fibula (Figure 27.11), the skin paddle can be marked and raised centred on these perforators.[12] As previously mentioned, a Doppler probe can also be used to mark the perforator sites.
3. The skin and subcutaneous fat is raised from the underlying muscle fascia using sharp dissection. The posterior crural septum will come into view, appearing as a white line directly over the lateral aspect of the fibula. Posteriorly soleus is identified, and peroneus longus and brevis with their longitudinally running muscle fibres are retracted anteriorly. The septum can then be followed onto the bone.

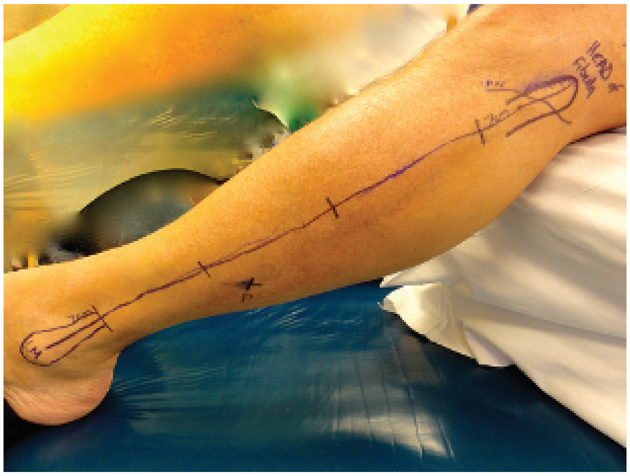

Figure 27.10 Surface markings.

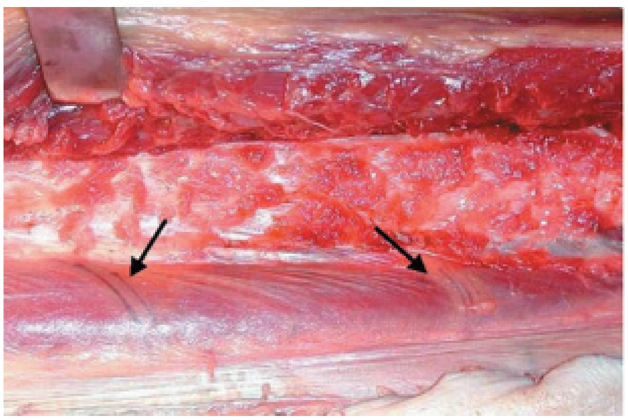

Figure 27.11 Two perforators can be seen emerging posterior to the fibula (arrowed).

4. Peroneus longus and brevis are detached from the lateral surface of the fibula using sharp dissection. The dissection passes anteriorly, along the whole length of the incision in a broad front, with detachment of the anterior crural septum, extensor digitorum longus and EHL. The safest way to do this is with sharp dissection, staying close to the bone but leaving a small cuff of muscle attached to it.
5. A thick white membrane (the inter-osseus membrane) will be encountered next (Figure 27.12). The anterior tibial artery and vein and the deep peroneal nerve are sometimes visible lying between this membrane and the underside of the tibialis anterior muscle. This vascular pedicle is retracted and the membrane is incised along its length using a pair of sharp scissors which are opened and slid along the membrane from proximal to distal (or vice versa) at a distance of about 1 cm from the fibula.
6. Attention should now be paid to the fibula bone cuts. The periosteum at the proposed bone cuts is incised. An instrument (such as a Macdonalds or Howarth's retractor) is gently passed around the deep surface of the

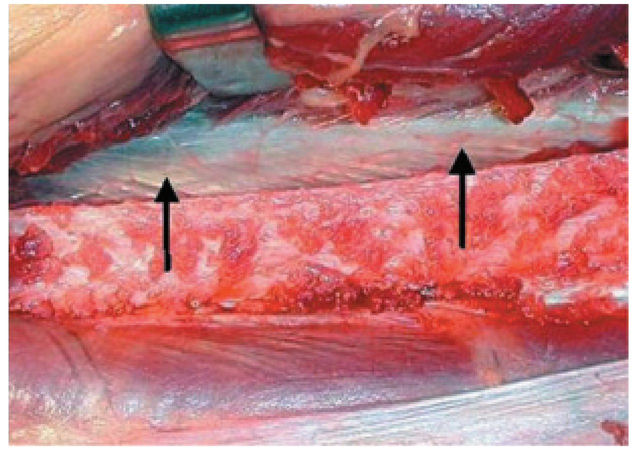

Figure 27.12 White inter-osseous membrane (arrowed).

fibula in a sub-periosteal plane to protect the underlying pedicle. The bone cuts (both proximal and distal) are performed with an oscillating saw. Some surgeons complete the cuts with an osteotome. The fibula should now be carefully retracted laterally using bone clamps. This procedure gives greater access to the peroneal vessels. When a longer pedicle is required, the amount of bone harvested can be increased by making a more proximal bone cut. The pedicle can be dissected free from this bone (and the latter discarded by making a further bone cut at the required length) once the flap is detached.
7. Gentle lateral traction of the fibula reveals the chevron-shaped fibres of tibialis posterior (Figure 27.13). The next stage depends on operator preference. Most surgeons will dissect through tibialis posterior at the distal bone cut site, using sharp and blunt dissection and staying close to the fibula (it is usual to leave 1 cm or so of tibialis posterior attached to the fibula). The peroneal vessels (artery and two accompanying veins) will readily come into view (Figure 27.14), and can be ligated and divided, thereby allowing the bone to be further retracted laterally. Others prefer to expose the length of the pedicle by dissecting along the length of tibialis posterior using sharp and blunt dissection. The advantage of the former method (and that preferred by the authors) is that the peroneal artery can be identified early, and followed up the fibula, in a manner not dissimilar to following the facial nerve during a parotidectomy – the overlying tibialis posterior can be lifted off the pedicle and safely cut.
8. If skin is required, the skin incision around the paddle is now completed (see Step 2). It is sensible to include a cuff of both FHL and soleus when completing this part of the dissection to include as many perforating muscular branches as possible.[6] The laterally retracted fibula flap can be moved from side to side, to ensure that this is done from both sides (laterally and medially), thereby reducing any chance of damage to either the main pedicle (Figure 27.15) or these perforators. As the skin and muscle paddle are released, it is wise to temporarily suture the paddle to the muscle cuff attached to the fibula to reduce the chance of shearing.

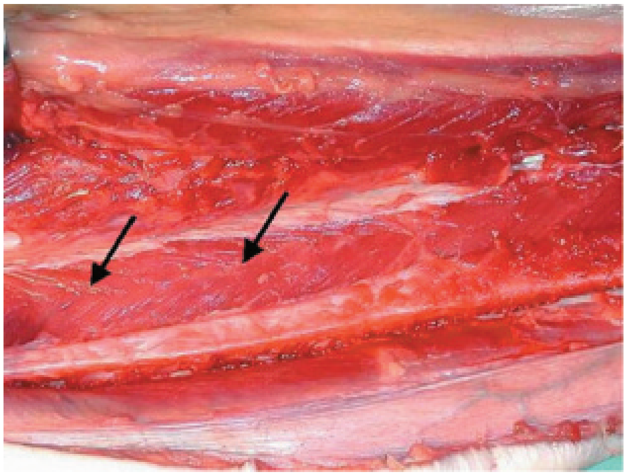

Figure 27.13 Chevron arrangement of the tibialis posterior muscle fibres.

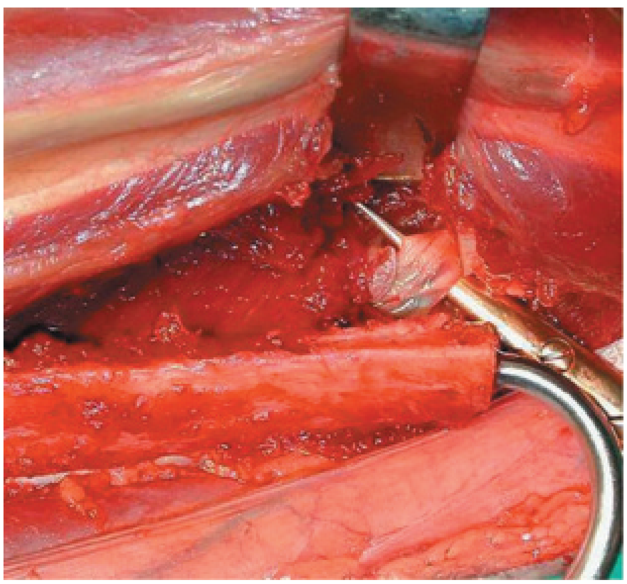

Figure 27.14 Identification of the distal pedicle.

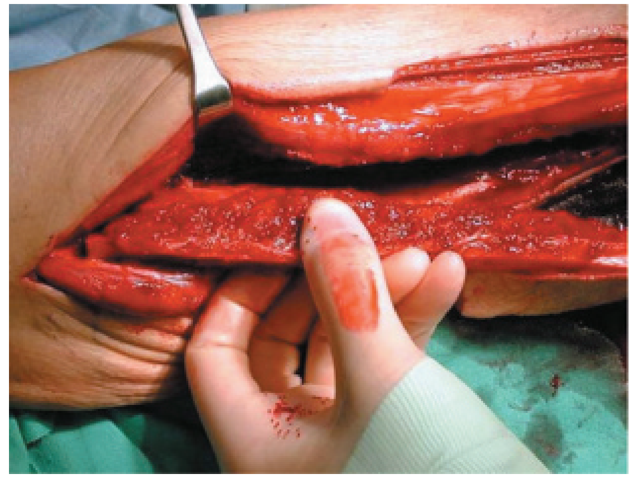

Figure 27.15 Flap is retracted laterally to aid dissection proximally.

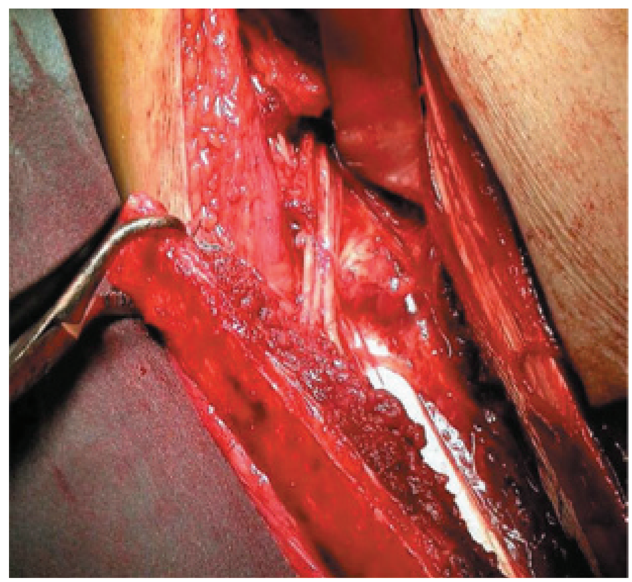

Figure 27.16 Proximal vascular pedicle.

9. As more of tibialis posterior is released, the flap can be retracted further laterally (Figure 27.16), revealing FHL and the posterior inter-muscular septum. The FHL is released from the fibula, taking care to ensure that the pedicle is not damaged during this procedure. Several perforating vessels arise from the peroneal artery and enter FHL, and if care is taken, these can be identified and dealt with before they are cut! The posterior tibial vessels are found more medially and should be left undisturbed.
10. Finally, any remaining muscle attachments are released from the fibula. Once the flap has been raised, it can be 'rested' in a heparinized saline-soaked gauze swap and temporarily placed back in the wound with the pedicle still running until it is needed for the reconstruction. When finally tying off the artery, a transfixation suture as well as conventional ligation ensures that the divided vessel will not inadvertently start bleeding post-operatively!
11. If osteotomies are needed to allow the fibula to satisfactorily fit the defect, these can be performed from the lateral aspect of the bone after the pedicle has been divided. Before these osteotomy cuts are made, the soft tissues and periosteum at the proposed bone cuts are carefully stripped off using sharp dissection and subsequently protected using a periosteal retractor. The cuts can be made with an oscillating saw on a sterile table, and completed with an osteotome. With the advent of

modern imaging and software, it is possible to accurately plan the osteotomy cuts in three dimensions, and to perform these cuts whilst the flap is still attached on the peroneal pedicle.[13] The flap is secured at the recipient site using the surgeons' choice of fixation (either a reconstruction plate or multiple 2-mm mini-plates). As already mentioned, the pedicle is sharply dissected off any excess bone to increase its length.

12. The wound is closed in layers by carefully suturing muscle groups together. A suction drain is also placed. When a skin paddle has been harvested, the defect is closed with either a full- or split-thickness skin graft. The latter can be taken from the thigh of the same leg, preferably using a powered dermatome.
13. Patients should mobilize early, initially with partial weight bearing. Ankle and foot movements are encouraged. Skin grafts should be managed in the conventional way. When patients are slow to mobilize, low molecular weight heparin prophylaxis should be considered.

Top tips

- Careful pre-operative assessment with imaging is recommended (either angiography or MRA).
- Correct leg positioning with adequate stabilization facilitates access.
- Surgical landmarks: Mark the fibula head and lateral malleolus and draw a line between them. Leave at least 7 cm of bone proximally and distally to maintain ankle joint stability and prevent damage to the common peroneal nerve.
- Always dissect on a broad front, and leave a small cuff of muscle attached to the bone.
- Identify cutaneous perforators early if a skin paddle is to be used (they emerge posterior to the fibula).
- Place a retractor sub-periosteally during proximal and distal bone cuts to prevent pedicle damage.
- The pedicle is always lateral to the tibial nerve in the posterior compartment.
- Proximal venae comitantes can be quite voluminous and fragile, so dissection should proceed with caution.
- Include a generous muscle cuff (FHL and soleus) when a skin paddle is raised.

ACKNOWLEDGEMENT

The authors would kindly like to thank Mark Richards, Salisbury Hospital, for providing Figures 27.7 through 27.9 of his innovative work.

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28

Vascularized iliac crest grafts

ANDREW LYONS

CONTENTS

PRINCIPLES AND JUSTIFICATION

Of all the free vascularized bone containing flaps, the vascularized iliac crest graft undoubtedly provides the best bone stock for orofacial reconstruction, supplying tissue to reconstruct the facial skeleton accurately, with ample bone for the placement of dental implants. Although a bone-only flap has been described which heals by epithelization, most flaps are probably raised to include some or all of the internal oblique muscle without skin. Although it is usually rather bulky, skin can be included, and even raised with the exclusion of muscle as a perforator flap.

The blood supply is from the deep circumflex iliac artery (DCIA) and venous drainage is from its venae comitantes. The pedicle is fairly short and fragile but the artery and particularly the vein are of adequate diameter of 2–4 and 2–7 mm, respectively. In most cases, there is a single artery and vein coming off the external iliac artery which usually divides within 1 cm into a deep branch supplying the ilium and lower transversalis, and an ascending branch supplying the muscles of the abdominal wall. Three approaches to the deep circumflex vessels may be utilized. The first approach is subinguinal. The femoral vessels are isolated below the inguinal ligament, and the deep circumflex iliac vessels are identified by upward retraction of the inguinal ligament. The transinguinal approach involves identification and retraction of either the spermatic cord or the round ligament and dissection through the transverses abdominus to expose the external iliac vessels. However, Taylor who first described this flap in 1979 noted the variability in the location of the large ascending muscular branch and warned that because of its size it was a potential point of confusion when trying to locate the DCIA. It is mainly for this reason that the superior approach using location of the distal pedicle on the under surface of the internal oblique muscle is the one preferred by the author.

The donor site can almost always be closed primarily, and if careful attention is paid to closure of the deeper tissues, there should be little long-term morbidity, even if the anterior superior iliac spine (ASIS) is harvested.

INDICATIONS

The flap is used for reconstruction of segmental mandibular defects in dentate patients, particularly anterior defects, and for reconstruction of maxillary defects that extend outside the maxillary alveolus (Figures 28.10 through 28.13). Where a cutaneous defect exists, the flap can be used to cover skin defects resulting from both maxillary and mandibular pathology. Additionally, where a large partial glossectomy has been carried out en bloc with an anterior mandible defect, the skin paddle can be used as a tongue resting on the internal oblique used as the floor of mouth. In either mandibular or maxillary reconstruction, the ipsilateral hip should be used. In the mandible, this can provide an ideal lower border angle or symphysis. In the case of midline defects, the flap should be raised ipsilaterally to the side where the pedicle is to be anastomosed.

Using the ipsilateral side in the maxilla gives optimal pedicle orientation and bone-to-bone apposition. The flap is contraindicated where there has been a previous iliac crest

graft, an inguinal hernia repair or abdominal incision for an operation such as appendicectomy. Patients with gait problems are not good candidates for this procedure in either limb. Obesity is only a consideration where a skin paddle is to be taken. In most cases of mandibular reconstruction, the contralateral side can be harvested instead, though some contouring may be lost at the lower border of the mandible.

PRE-OPERATIVE

The area around the iliac crest should be checked for visible scars in case this was missed in the history. There is a large thickness of subcutaneous fat in this area, and in many patients this will render the skin unsuitable for reconstruction. If a skin paddle is to be harvested, the use of a handheld Doppler is advocated to locate the perforators. There is a fairly consistent perforator 5 cm lateral and 2.5 cm above the ASIS and other perforators may be found laterally at a similar distance above the iliac crest. A template can be used to aid in bone harvest, and this should ensure accurate fast bone harvest. This should be constructed pre-operatively, with the aid of a three-dimensional computer tomography (3D CT) of the jaw which can be converted into a model and template. The patient should be warned of post-operative pain and discomfort, numbness at the front of the thigh and that gait is likely to be abnormal for at least 3 months.

OPERATION

Positioning the patient

With the patient supine, a large sandbag is placed beneath the hip, and skin preparation should be across the midline medially, at a lower level than the greater trochanter inferiorly, laterally past the post-axillary line and superiorly just above the costal margin. A sigmoidal line is drawn from the pubic symphysis, along the superior border of the iliac crest which should be palpated, to the posterior axillary line. If a skin paddle is to be harvested, it should be marked out following perforator location with a Doppler probe (Figure 28.1).

Incision

Along the length of the incision, the skin and fat are incised through Scarpa's and Camper's fasciae to the external oblique muscle whose fibres run in a downwards and forwards direction; this should obviously run around the skin paddle if one is to be raised. The muscle should be incised in the direction of its fibres to the underlying internal oblique muscle which has a very distinctive downwards and slightly backwards orientation (Figure 28.2).

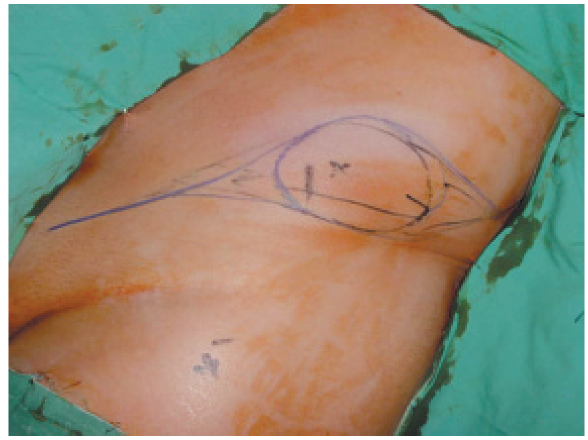

Figure 28.1 Skin markings or flap with skin paddle, the X marks the Doppler signal point. The lower line would be appropriate for a myo-osseous flap (left side).

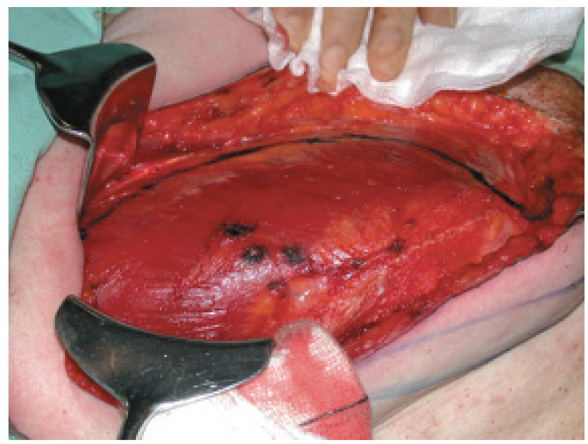

Figure 28.2 Exposure of internal oblique muscle, left-sided flap.

If a skin paddle is to be raised, the perforators should be identified, and a cuff of external oblique muscle should be left around the perforators.

The only exception to this is if it is planned to raise an osseocutaneous flap devoid of muscle where the muscle layers are opened to permit tracing the pedicle to the ascending or main branch of the DCIA (Figures 28.3 and 28.4). This technique will not be discussed further; only surgeons with extensive experience of vascularized iliac crest grafts should carry out this procedure which has been well described by Kimata.[1]

Exposure of the internal oblique

The external oblique muscle should be incised along the whole length of the crest, and this incision should be extended medially, its lower border the inguinal ligament.

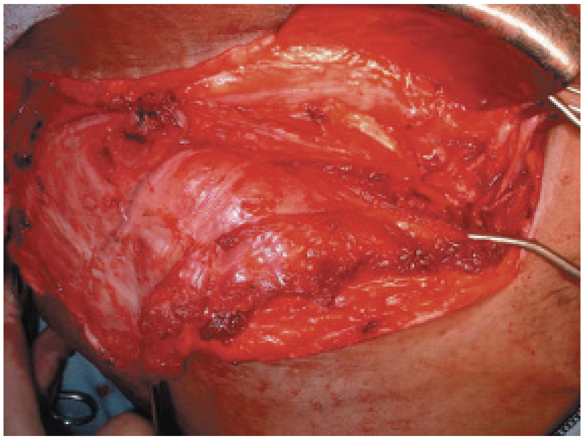

Figure 28.3 Undersurface of internal oblique showing ascending branches and deep circumflex iliac artery in a right-sided flap.

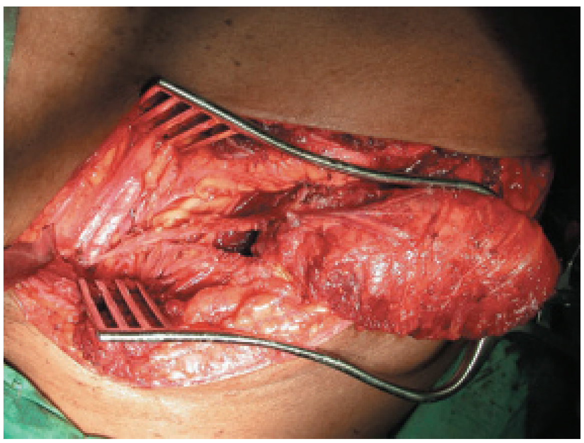

Figure 28.4 Complete flap with pedicle (left side).

The muscle should then be elevated superiorly detaching it from the underlying internal oblique muscle.

Raising the muscle flap

Once the internal oblique muscle has been exposed commensurate with the amount to be harvested, the portion required should be marked out with ink. In mandibular reconstruction, the iliac crest is best utilized as the lower border, and the estimate for the amount of muscle to be harvested should include that required to run from 'the lower border' into the buccal sulcus. It is recommended to harvest at least 4 cm of muscle from the upper border of the iliac crest. In the rare event that there is only an ascending branch of the DCIA, the flap will have to rely on this vessel.

The incision through the internal oblique muscle should commence at the superolateral aspect of the muscle and should extend below the transversalis fascia onto this muscle. The internal oblique and transversalis fascia should be raised by sharp dissection. Meticulous haemostasis to the many perforating vessels which run through the two muscles is required using bipolar diathermy. Dissection should proceed in an inferolateral direction as this will release the assistant from the tiresome job of pulling a large bulk of skin fat and external oblique muscle upwards.

Dissection of the pedicle

The ascending branch will soon be visualized, and as dissection proceeds, this will become larger. At this stage, dissection should proceed inferiorly to expose a possible 'lower ascending branch', as there is frequently branching of the ascending branch. As the dissection proceeds inferiorly, the DCIA itself will be encountered. This may be above or below the iliacus muscle as it inserts into the ilium but a small 1 cm or less cuff of muscle should be left around the vessel to safeguard it. The author realizes that other descriptions involve not locating the DCIA alongside the ilium but harvesting 2 cm of iliacus to preserve it. In the author's experience, this is the minimum muscle required for a safe 'blind approach'.

Dissection should now proceed medially and the internal oblique muscle incised superomedially laterally to aid this. There should at least be a small length of muscle left above the ascending branch but more muscle may be required, and the only limitation is the extent of the muscle at the costal margin superiorly and rectus sheath medially, although a cuff of muscle should always be left to aid in repair. It is tempting to harvest as little internal oblique muscle as possible, but it should be remembered that in reconstructing high dentate mandibles 4 cm of muscle may be lost just to bring the muscle into the mouth.

As the dissection proceeds medially to the ilium, the overlying internal and external oblique muscles will need to be incised to the medial end of the ilioinguinal ligament.

Attention must be paid to vessels branching off the pedicle which if violated will bleed causing a loss of pedicle visualization (Figure 28.5). These are best ligated with metal clips rather than using diathermy, to protect the pedicle. About 2 cm from the external iliac vessels, the ascending branches will join the pedicle, and at about this point, the vein which is 2–3 mm in diameter will start to dilate as it curves upwards and medially to course over the DCIA and external iliac artery before joining with the external iliac vein at a diameter of 4–8 mm. This requires meticulous dissection as the veins can be quite thin walled, and the wide vein with the 1.5–2 cm length over the artery that can be achieved may be crucial as the defect may not be ready for the flap. It is recommended to delay this dissection until the time has been reached for pedicle division and delivery of the flap.

Although the anatomy of the pedicle is fairly constant, there is some variability. The ascending and main deep circumflex vessels may join the iliac vessels separately,

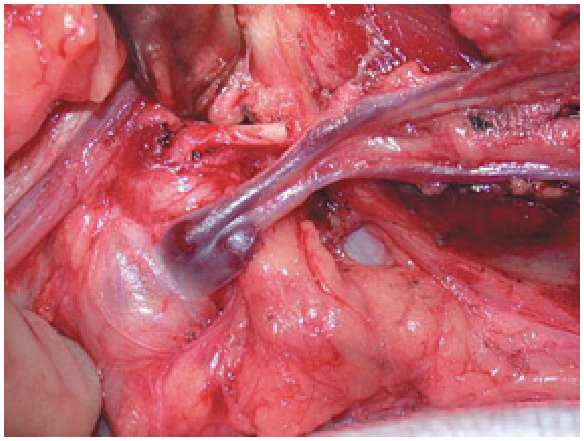

Figure 28.5 Junction of pedicle and external iliac vessels (right side).

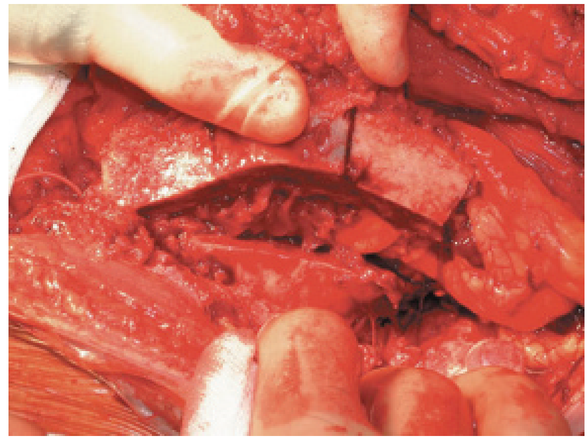

Figure 28.6 Osteotomy cuts in left-sided flap. This has been made to preserve the anterior superior iliac spine and inguinal ligament. Note that the two incomplete osteotomy cuts that will be greenstick fractured later.

giving duplicate pedicles. Although it may be possible to run the flap on one set of vessels, ideally all these vessels which are usually less than 2 mm in diameter should all be anastomosed. Occasionally, only the ascending branch will originate from the external iliac artery with the main DCIA originating from the internal iliac artery. The pedicle should now be traced backwards towards the ilium separating the pedicle from the underlying psoas muscle. At a point 2–3 cm medial to the ASIS, the lateral cutaneous nerve of the thigh will be identified and the pedicle should be dissected off this structure. It is however, advocated that those with early or little experience of this flap should sacrifice this nerve if they are in any doubt about the pedicle being at risk.

Bone harvesting

The point at which bone harvest should commence along the length of the ilium depends on three factors:

1. Quantity of bone required: this flap will reach the contralateral ramus with total ipsilateral reconstruction, but the entire length of the ilium that can be harvested with the muscle and pedicle will be required.
2. Part of the mandible to be reconstructed: the anterior crest is an ideal shape for mandibular angle reconstruction. The anterior mandible does not require the anterior crest, and by taking the bone 3 cm lateral to the ASIS, this will be 3 cm extra pedicle length.
3. If the maxilla is to be reconstructed the requirement for bone length is not usually great, but the requirement for pedicle length may be critical. Therefore the bone harvest should commence as far away laterally from the ASIS as possible.

If the anterior crest is to be harvested after detaching the inguinal ligament, the gluteus medius muscle should be stripped from the outer aspect of the ilium to match the template. If the anterior crest is not to be harvested, the periosteum should be stripped from the inner aspect of the ilium to where the medial bone cut is to be made. It is important to leave the gluteus medius attached to the outer aspect, otherwise the anterior crest can become avascular and may dehisce through the wound. The bone is cut with a saw, and the medial and lateral beginning and end cuts should be made with a small copper retractor or periosteal elevator, protecting the underlying periosteum and pedicle. The template even if just constructed intraoperatively should give an idea of where any 'intra-flap' osteotomy cuts are located, and it is the author's preference to make these cuts in situ as the bone is held rigid here. These osteotomy cuts should not perforate the inner cortex, this can be greenstick fractured later to preserve the periosteum (Figure 28.6). The horizontal cut can now be made with a retractor situated medially to protect the peritoneum. Once the osteotomy cuts have been made, an osteotome should be used gently to mobilize the bony flap, which should be carefully handled out of the pelvis (Figure 28.7).

Closure of the donor site and pedicle division

Any obvious bleeding should be attended to; only bipolar diathermy can now be used on the flap, as all current from a monopolar diathermy may be transmitted by the narrow pedicle only with the possibility of thermal damage. Bone wax should be placed over the trabecular bone of the donor site. Once it has been ascertained that the flap including the bone is bleeding, attention should be drawn to the donor site, most of which can be closed before detaching the pedicle. Bone wax should be placed over the trabecular bone. The abdomen should then be

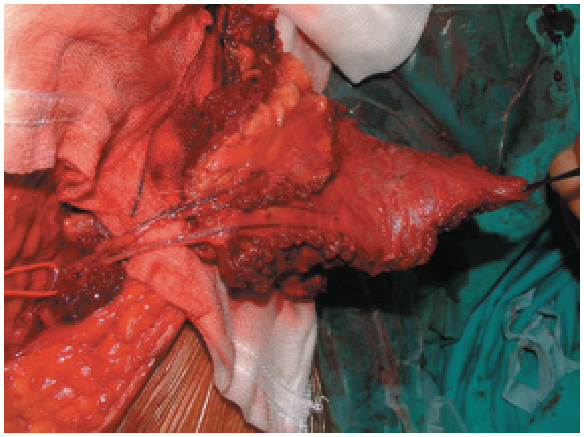

Figure 28.7 Left-sided flap and pedicle.

closed in layers. To aid this, a series of holes are made approximately 1 cm apart along the inner and outer cortex of the bony defect in the ilium.

It is recommended to use 1 or 1/0 nylon sutures and temporarily hold them with artery clips until all the sutures have been placed before tying the knots. A piece of non-resorbable mesh should be trimmed to the size of the internal oblique defect. This is sutured to the outer cortex of the ilium and the internal oblique muscle with a round-bodied needle, 1 or 1/0 nylon suture with the knots being tied immediately (Figures 28.8 and 28.9). A suction drain with a minimum intra-luminal diameter of 3 mm should be placed over this layer and an epidural catheter teased through one of the sutured muscle layers. Both of these devices should be secured to the skin with a suture immediately after introduction. Closure of the muscle layers medial to the ilium has to be delayed until pedicle division.

Division of the pedicle

Final dissection of the proximal pedicle should be undertaken and the artery and vein divided and ligated. The flap should be carefully handled to avoid twisting the pedicle. The lumen of the artery is identified, and a small nylon cannula is introduced into it to permit flushing of the flap with 20–50 mL of heparinized saline.

The muscle medial to the donor site is closed in layers. The inguinal ligament if detached is sutured to the ilium, and the external oblique muscle is closed to itself medially and to the gluteus medius muscle laterally. Even if a large skin flap has been harvested direct skin and subcutaneous tissue closure is assured.

Insetting and anastomosis

The bony component of the flap should be adjusted with a saw if required, rotary instruments are not recommended in case the pedicle is snagged and torn. The bone should be fixed with the appropriate screws and plates. In contrast to the fibula, the iliac bone is contoured using opening osteotomies with simple splitting of the bone prior to spreading the bone around the cut. This will increase the bone length. Cancellous bone chips can be used to fill the resultant bone gap. The muscle and skin should just be tacked

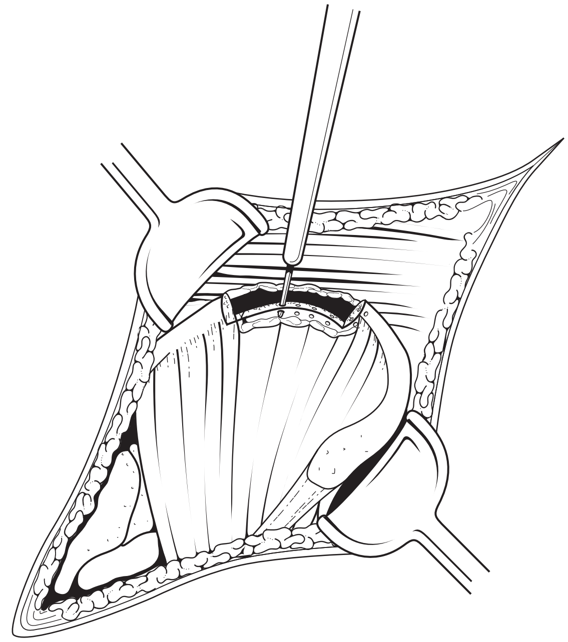

Figure 28.8 The transversalis and parts of the iliacus are sutured into these holes with a round body needled 1 or 1/0 nylon suture. It is recommended to temporarily hold the sutures with an artery clip until all the sutures have been placed before tying the knots.

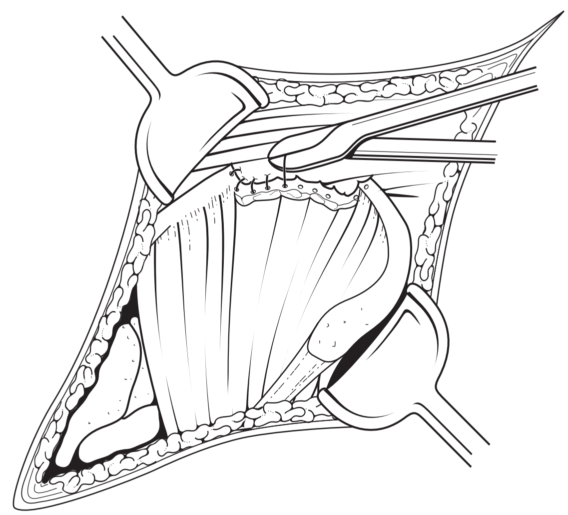

Figure 28.9 A piece of prolene mesh or similar material is trimmed to the size of the defect in internal oblique.

Figure 28.10 Mandibular reconstruction showing excellent bone bulk for dental implants.

in place to orientate the pedicle, and the anastomosis carried out at this stage.

In the author's personal experience, the vein is best anastomosed first. This allows no interruption of flow through the artery once this anastomosis is complete. At 5 minutes before the artery is allowed to run, 5000 units of heparin are administered intravenously; this is not the usual practice of the author for any other flap. The DCIA is a relatively small vessel and before it was the author's practice to use heparin, many flaps would start to run before stopping after 10–20 minutes. It may be that the heparin prevents fibrin degradation products in the previously ischaemic tissue setting off the clotting cascade when fresh blood enters the vessels, and to date this technique has allowed 40 consecutive DCIA-based flaps to run perfectly following clamp removal.

After the flap is running, the internal oblique muscle is sutured into the intra-oral defect. Some muscle trimming may be required, but although the flap may appear very bulky at this stage, it is likely to shrink back in a matter of weeks and certainly after radiotherapy. If there is a skin flap, this can now be inset (Figure 28.11).

POST-OPERATIVE

If there is a skin paddle, the artery can be easily monitored with a handheld Doppler probe and assessed for pallor, although it is possible that the state of this flap based on a small perforator may appear less perfused and less drained than the muscle and bone. A handheld Doppler can assess arterial flow of the pedicle within the neck. For venous monitoring, the colour of the flap, which will obviously appear dark if engorged, is useful. Stabbing the muscle may be useful; bright red blood should flow rapidly, and if individual muscle fibres can be seen, it probably signifies the flap is not working. The muscle should ideally have a 'glazed toffee apple appearance'. A Doppler probe sutured around the flap side of the venous anastomosis may also be helpful. None of these methods are 100% reliable, and it is fair to say this is a difficult flap to monitor. The muscle component of this flap should be epithelized by 72 hours. Local anaesthetic can be infused through the epidural catheter to aid in analgesia (Figures 28.12 and 28.13).

Figure 28.11 Maxillary reconstruction. *Note:* multiple osteotomies and internal oblique muscle prior to suturing into position.

Figure 28.12 Mandibular reconstruction on right (pre-implants).

Figure 28.13 Maxillary reconstruction. *Note:* reconstruction crosses midline.

COMPLICATIONS

Intra-operative

- Damage to the small delicate pedicle is always possible. This is most likely to occur to the main deep circumflex iliac (DCI) vein behind the medial portion of the ilium where it can be buried in the iliacus muscle.
- Violation of the thin transversalis muscle to produce herniation of pre-peritoneal fat is always a possibility but can be closed.
- Snagging of the pedicle with a rotary instrument is possible and potentially disastrous; use of these instruments should be minimized in this operation.

Post-operative

- Loss of flap perfusion and venous drainage are particular problems in maxillary reconstruction.
- Partial necrosis of the internal oblique muscle may occur but is not usually a problem as granulation over vital bone will absolve this.
- Partial bone necrosis can be more of a problem and is of course more likely to occur with small distal segments of osteotomized bone.
- Seromas may occur probably as a result of damage to the external iliac lymphatics.
- Post-operative infection particularly associated with the internal oblique mesh can be very troublesome and may even require removal of the mesh. It is advisable to handle this material carefully and apply topical antiseptics to the mesh bed and mesh itself to reduce this.
- Incisional hernia is always possible if the layers of the donor site are not closed with care.
- Numbness to the anterior thigh due to damage to the lateral cutaneous nerve may be troublesome to some patients.
- Gait problems may last 6 months or even longer especially in the elderly.

Top tips

- Always ensure enough muscle is harvested in mandibular defects. Distal bone fragments can sometimes have a precarious blood supply. A thick covering of richly supplied muscle will hence sometimes be invaluable.
- Where pedicle length is likely to be an issue (usually maxillary cases) use the smallest amount of bone harvested as far back along the iliac crest as possible, to lengthen the pedicle.
- Do not underestimate the time, complex nature and importance of carefully closing the donor site defect. In some quarters, this flap has acquired a reputation for medium- and long-term morbidity, both of which can nearly always be avoided by attention to detail.

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29

Facial reanimation

HENNING SCHLIEPHAKE

CONTENTS

INDICATIONS

Facial reanimation is indicated in cases of acquired long-standing facial paralysis or in congenital disorders associated with a decrease in facial muscle activity such as the Möbius syndrome, congenital unilateral lower lip palsy (CULLP) or even hemifacial microsomia. Acquired long-standing facial paralysis most frequently results from neurosurgical or otolaryngological interventions for intracranial tumours as central palsy but may as well occur after ablation of malignant parotid tumours as peripheral palsy. After long-standing paralysis, a transfer of nerve grafts alone is insufficient to restore facial movement as functional muscle tissue has almost disappeared.

Facial reanimation encompasses surgical measures that support or restore facial movement in cases of facial nerve palsies. In contrast to static reconstructions such as suspension plasties to raise the oral commissure or lateral canthopexy to alleviate the sequelae of orbicularis oculi muscle palsy, these procedures allow for active movement of facial muscles either by supporting existing muscular activity or by transferring neuromuscular units from adjacent or distant sites to the deficient area. As voluntary and involuntary facial movement is accomplished by 18 separate muscles that are unique in their way to produce individual facial expression, even dynamic functional reconstruction using revascularized transfer of neuromuscular units does not always restore symmetry in unilateral facial palsy.

There are three areas in which muscle function can be restored through dynamic facial reanimation: the eyelids for eye closure and protection of the globe, elevation of the oral commissure to achieve oral continence and lower lip depression to complete facial expression. Eyelid closure is often approached statically by metal implants into the upper eyelid to support lid closure. Dynamic function with blink restoration of can be accomplished by pedicled transfer of frontalis or temporalis muscle as well as free neuromuscular transfer. Dynamic reanimation of oral commissure movement is achieved by pedicled temporalis muscle insertion but more often using free neuromuscular transfer, mostly gracilis muscle subunits. Restoration of depressor function can be restored by transfer of digastric or platysma segments.

This chapter focusses on the most common neuromuscular transfer in facial reanimation, the free transfer of subunits of the gracilis muscle for reanimation of oral commissure movement.

PRE-OPERATIVE PLANNING

Timing

Symmetric innervation of the transferred muscle segment is crucial for a successful reconstruction. This does not only relate to voluntary movement but even more to spontaneous emotional expression. As the facial nerve is the only cranial nerve that spontaneously produces impulses during facial expression, it is considered as the source of choice for neurotization. The hypoglossal nerve and the motor nerve supply to the masseter muscle have also been used as source of innervation to a muscle graft, but could

not achieve the degree of symmetry that the facial nerve provides.

In cases of peripheral nerve palsy, the ipsilateral facial nerve stump could be used. However, as the individual fascicles of the nerve are assigned to different facial regions, appropriate selective neurotization through one of these fascicles is difficult without the possibility to check for their original assignment and avoid synkinetic movement of the 'wrong' contralateral muscles. Therefore, in peripheral and even more in central facial nerve palsy, the contralateral facial nerve is the preferred source of innervation. Nerve impulses from the contralateral side are conducted to the paretic side through a cross-face nerve graft. Thus, free neuromuscular tissue transfer for facial reanimation is a two-step procedure with the first step being the cross-face nerve graft from the opposite side and the second step performing the muscle transfer 9–12 months after nerve grafting.

OPERATION

Cross-face nerve graft

1. *Graft procurement:* The sural nerve is commonly used as donor nerve for the cross-face nerve graft as it provides adequate length to crossover to the opposite side of the face. The nerve runs down the leg on the postero-lateral aspect of the calf where it passes to the lateral side of the foot approximately 2 cm posterior to the ankle. Here it is easily exposed from a small horizontal incision of 1–2 cm length. After identification of the nerve trunk, a second transverse incision some 4–5 cm proximal is placed on the calf slightly more posterior than the first one. The nerve is identified and connection with the exposed nerve segment further distal is established by subcutaneous dissection. The same is carried out again 4–5 cm more proximally. The nerve is then divided below the most distal incision and removed in a proximal direction. Care must be taken to avoid tearing of the branches, which have to be identified by subcutaneous dissection and separated from the main trunk. In this way, a nerve segment of 10–12 cm length can be obtained. The small incisions are closed and a moderate compression dressing with decreasing pressure from distal to proximal is applied.
2. *Facial nerve preparation:* The sural nerve graft is connected to one or two branches of the facial nerve on the opposite side and that provides impulses to the area that is supposed to be reconstructed on the paralyzed side. In this way, symmetric innervation and facial expression are intended. Commonly, the muscles that elevate the oral commissure receive motor nerve supply from the buccal branches of the facial nerve. This part of the nerve contains multiple branches that are connected to each other, so that division of one or two small branches does not compromise facial nerve function on the non-paralyzed side of the face. In order to allow for identification and selective dissection of these branches using electrical testing, general anaesthesia has to be administered without muscle relaxation.
   a. The patient should have his endotracheal ventilation tube inserted through the nose. His head has to be positioned and draped in a way that allows turning of the head and provides access to both parotid areas as well as visual control of peri-oral and peri-orbital muscles.
   b. Exposure of the facial nerve branches starts from a pre-auricular incision after elevation of the facial skin superficially to the parotid fascia (Figure 29.1). Good visualization is mandatory for safe exposure and reliable identification of the individual nerve branches as well as microsurgical coaptation between the branches and the sural nerve graft later on. Thus, if required, the incision is extended superiorly across the hair line and inferiorly around the mandibular angle into the submandibular area. Despite a rather long incision line, the resulting scar is less conspicuous than the vertical cheek incisions that are recommended otherwise for direct access to the nerve branches.
   c. When the anterior edge of the parotid gland is reached, dissection is continued along the fascia into the fat tissue where the branches leave the gland. As the branches are below 1 mm in diameter, this part of the operation requires careful dissection with repeated use of the nerve stimulator to identify the precise function of the individual branches (Figure 29.2). Redundance of innervation is mandatory for those functions that are accomplished by the branches selected for coaptation with the cross-face nerve graft to avoid loss of function on the non-paretic side. Thin rubber slings are used to mark these branches and the dissection is carried on in the subcutaneous plane anteriorly to the nasolabial crease.

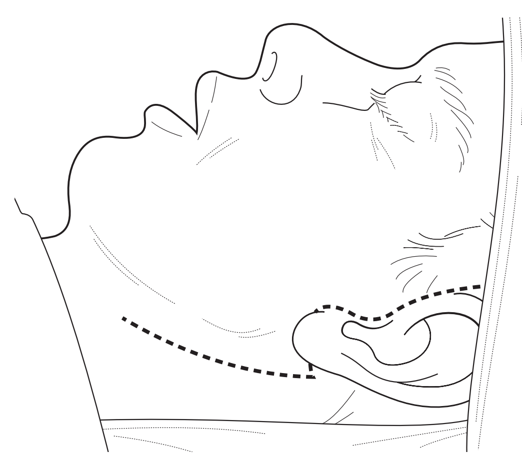


Figure 29.1 Pre-auricular incision line that is extended submandibular.

d. The pathway for the nerve graft to the opposite side of the face runs through a subcutaneous tunnel in the upper lip. This tunnel is prepared from bilateral curved incisions at the alar base and a contralateral pre-auricular incision. The former ones are used for subcutaneous dissection from midline to the nasolabial fold (Figure 29.3). The latter incision is placed in a facelift like fashion and the parotid area is exposed by extracapsular dissection after elevation of a facial skin flap. When the subcutaneous tunnel is finished a thin and curved long forceps is inserted from the paretic to the non-paretic side.

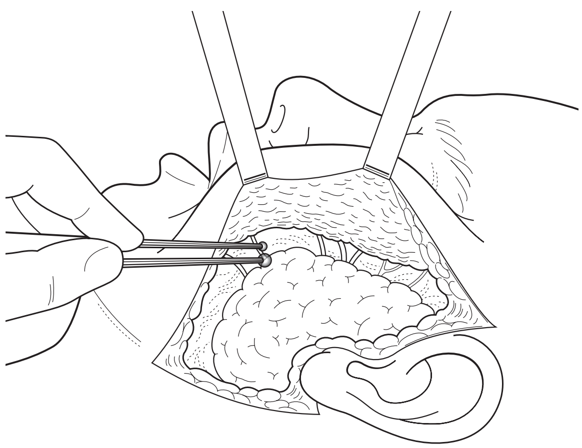


Figure 29.2 Dissection of small branches of the facial nerve exiting the gland at the anterior margin. Nerve testing to prove redundance of nerve supply in the buccal and zygomatic region.

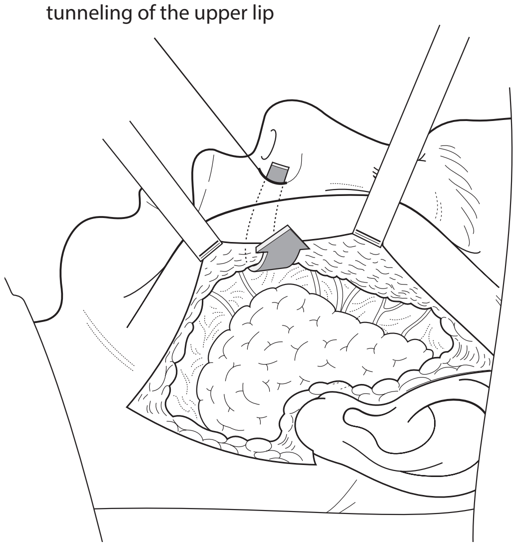


Figure 29.3 Pre-auricular incision and subcutaneous dissection to the upper lip, continued to the contralateral side by bilateral bow-shaped incisions at the nasal alar base.

The proximal end of the nerve graft is grasped and guided through the tunnel to the paralyzed side. In this way, it is ensured that coaptation of the facial nerve branches is not inadvertently done to fascicles that run into side branches that have been divided or torn during harvest. The nerve is placed high in the upper lip immediately underneath the collumella and the alar base in order to avoid interference with the dissection during muscle transfer later on.

e. Interfascicular nerve coaptation between the selected facial nerve branches and the sural nerve graft is done under the microscope using 11-0 sutures. It will not be possible to connect all fascicles of the nerve graft to the small facial nerve branches, but it is important to make sure that the fascicles of the facial nerve branches are securely connected to individual fascicles of the sural nerve graft. The end of the nerve graft on the paralyzed side is fixed to the parotid fascia by a non-resorbable 3-0 suture that can be easily identified and dissected 9–12 months later during muscle transfer. Suction drainage with a 10-gauge drain on either side and skin closure in layers complete the operation. It is important to ensure that the drain is not located in the vicinity of to the coapted nerve branches to avoid inadvertent damage during drain removal.

Muscle transfer

Planning: After a minimum wait of 9 months, the muscle transfer can be planned for restoration of oral commissure movement and/or eye closure. In order to achieve a symmetric smile, it is important pre-operatively to do the following:

- Define the desired position of the modiolus at rest with the patient sitting in an upright position.
- Identify the vector and the extent of movement of the commissure during smiling.

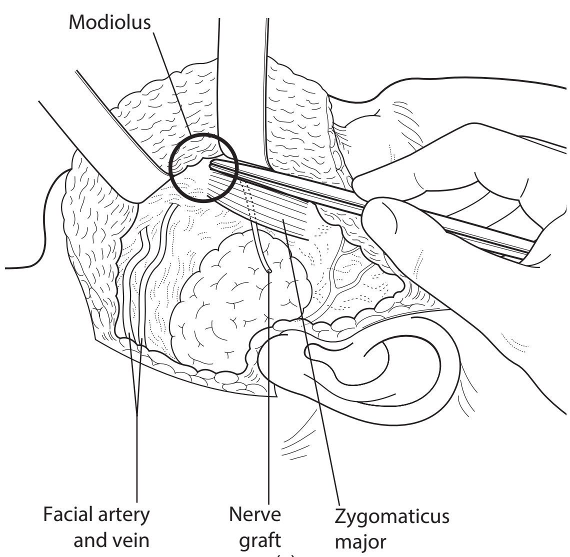
The commissure and the nasolabial crease are marked on both sides with a waterproof pen on the immediate preoperative day. The difference between the actual and the planned position of the commissure at rest is registered on the paralyzed side with a ruler. The extent of movement of the commissure during smile on the non-paralyzed side is also measured directly using the ruler and the direction of movement is marked on the skin with an arrow. These marks will have to be renewed after facial skin disinfection and draping immediately before the operation starts. The required length of the muscle graft can be estimated from the distance between the zygomatic bone prominence and the position of the modiolus at rest.

Preparation of the recipient side

The facial skin on the paralyzed side is elevated from the pre-auricular incision, which is extended to the submandibular area. Subcutaneous dissection is carried on to the lower border of the mandible where the facial vessels are

identified and exposed to be used as recipient vessels for the muscle graft. The end of the cross-face nerve graft that had been fixed to the parotid fascia is released and adequate regeneration is confirmed clinically by a positive Tinel's sign and histologically after removal of a small portion of the nerve for frozen section analysis. Elevation of the skin is continued medially until the oral commissure and the malar prominence are reached. This exposes the paralyzed zygomaticus muscles, the action of which is supposed to be replaced by the muscle graft (Figure 29.4a).

The tissue underlying the commissure is grasped with a forceps and pulled gently in a cranial direction towards the zygoma while the formation of creases and the change in the shape of the commissure is observed (Figure 29.4b).



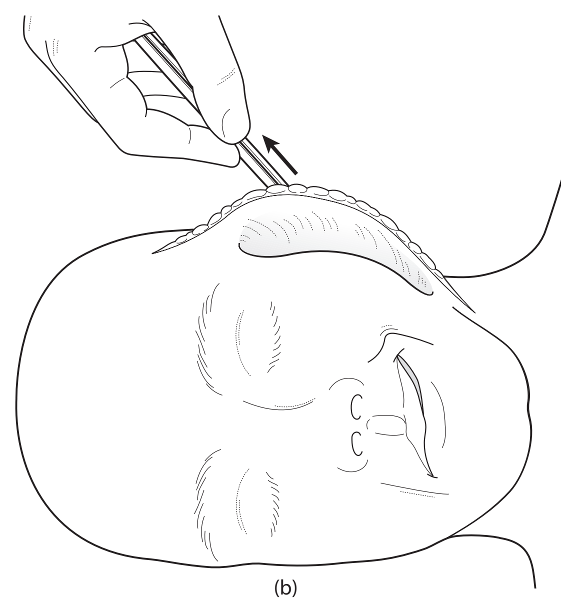


Figure 29.4 (a) Exposure of the zygomaticus muscle and identification of the modiolus. (b) Traction to the commissure to define the 'smile pattern'.

The traction points will have to be modified slightly and the procedure repeated until a satisfactory smile shape results. This traction point is secured with a permanent suture that is left open. Commonly, one or two more traction points are needed to produce a movement and shape that mimics that of the normal side. These are explored while the central point in the commissure is 'activated' by pulling the suture. In this way, additional points are identified and secured with sutures. The additional points are commonly found slightly more medial to the commissure in the upper lip and below the central point in lateral portion of the lower lip.

Insertion of the muscle graft: The muscle is harvested according to the procedure described in Chapter 26. The graft is placed on the recipient side with the point of entry of the vascular pedicle and the nerve on the undersurface of the muscle. The muscle length should be roughly adapted according to the distance between the commissure in a simulated position at rest and the malar prominence. This is advisable to avoid asymmetric positioning of the neurovascular pedicle that may occur if the muscle is shortened after one end has already been fixed. Usually a length of 6–7 cm is used in this position.

The graft end that faces the commissure is divided into two or three portions depending on the number of traction points identified (Figure 29.5). The muscle ends are attached separately to the upper lip commissure and if required to the lower lip. Fixation to these points is done with 2-0 or 3-0 resorbable mattress sutures. Excess muscle volume at the points of fixation is reduced by excision of muscle fibres from the centre of the graft ends in order to preserve the epimysium for secure fixation. The stay sutures that have been fixed to the traction points are activated to elevate the commissure to a position that is symmetric to the position at rest on the normal side according to the pre-operative measurements. They are transcutaneously fixed over lead buttons above the malar prominence

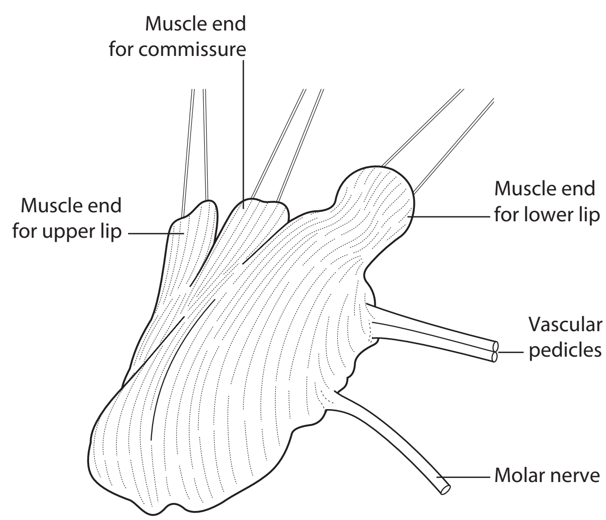


Figure 29.5 The graft end is divided into three parts before it is fixed to the oral commissure.

(Figure 29.6). The upper end of the muscle is securely fixed to the periosteum of the zygoma by multiple mattress sutures in the direction of the vector defined by the stay sutures. The muscle length should be adapted in a way that there is slight tension on the muscle.

Vascular anastomoses of the graft vessels with the facial vessels are done under the microscope using 9-0 or 10-0 sutures depending on the diameter of the graft vessels.

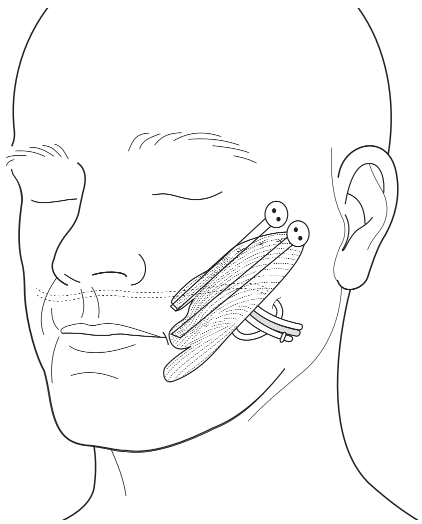


Figure 29.6 Positioning of the graft and the stay sutures.

Occasionally, spasm of the facial artery occurs, which can be released by carefully applying papaverine to the end of the facial artery. Interfascicular coaptation of fascicles of the muscle's motor nerve to the cross-face nerve graft is done using 11-0 sutures. Coaptation should be close to the muscle to allow as early re-innervation by regenerating axons from the cross-face nerve graft as rapidly as possible.

Before wound closure, the stay sutures should be checked to make sure that the new position of the commissure is held by the sutures and not by the muscle. A 10-gauge suction drain is placed in the submandibular area and the tip of the drain is kept away from the facial vessels to avoid damage during removal.

POST-OPERATIVE CARE

Post-operative care of the donor leg is described in Chapter 26. The suction drainage is routinely removed on the second post-operative day. Patients are asked not to activate their facial muscles on the normal side of the face to avoid tension and dislocation on the reconstructed side. The stay sutures are left for 3–4 weeks to allow for consolidation of the connection between the grafted muscle tissues in the points of fixation. Four weeks after the operation, transcutaneous electrical stimulation of the grafted muscle is started to avoid muscle atrophy during nerve regeneration (Figure 29.7a and b).

(a)

(b)

Figure 29.7 (a) Long-standing facial paralysis at rest (left) and during activation (right). (b) Three months after repair (gracilis graft) at rest (left) and during activation (right).

Complications

Complications are rare with respect to bleeding or wound break down. A major complication is the inability of the muscle graft to take on action. This only becomes evident some 25–30 weeks after the muscle transfer. Electromyography at this time can prove existing or missing voluntarily muscle contractions. Failure to show signs of activity may be due to insufficient vascularization or missing re-innervation. Insufficient vascularization has to be excluded by a meticulous technique of microvascular anastomosis as monitoring of the graft after wound closure is impossible. Reliable graft perfusion through patent anastomoses has to be proven by a positive Acland test and clear signs of muscle perfusion before wound closure. Failure to re-innervate the muscle may occur if the cross-face nerve graft has too few actively regenerating axons. This has to be excluded during muscle transfer by a positive Tinel's sign and histologically by frozen sections.

Top tips

Success in facial reanimation by neuromuscular tissue transfer is very much based on symmetry of facial expression. In order to achieve this, a few things should be kept in mind during the surgical procedures.

- A crucial point is a functioning nerve supply. Thus, coaptation of the cross-face nerve graft to the facial nerve on the non-paretic side must be done with greatest possible care in that the fascicles of the selected branches are reliably connected to fascicles at the distal end of the nerve graft.
- The nerve graft should be long enough to reach the pre-auricular incision line to allow for a tensionless coaptation with the graft nerve, which in turn should be as short as possible to shorten neurotization time.
- The muscle graft should be positioned in an almost vertical fashion from the modiolus to the malar prominence to ensure vertical movement of the commissure during activation.
- The position of the commissure at rest must be safely secured by the stay sutures and the lead buttons and the grafted muscle should be under moderate tension in this position. A slight overcorrection will compensate for the tendency of sagging of the soft tissues after removal. Correction of the position of the commissure later on by activation of the stay sutures is barely tolerated by the patients.

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30

Laser: General principles

MADANGOPOLAN ETHUNANDAN and COLIN HOPPER

CONTENTS

LASER is an acronym for Light Amplification by Stimulated Emission of Radiation. The laser light is a type of electromagnetic (EM) radiation and is derived from the optical part of the EM spectrum. Radiation is considered energy in transit and its propagation can be influenced by changes in the energizing source. The laser light travels in waves, which have characteristic wavelengths and frequency.

PHYSICS AND DEVICES

The physics of laser is a complex topic; Albert Einstein published the theoretical basis of laser in 1917, but a functioning laser light was only produced in 1960 by Theodore Maiman. In brief, atoms consist of a positively charged nucleus and negatively charged electrons, which orbit in precise energy levels. At rest these electrons remain at the lowest energy level (ground state) and when energy is added, are elevated to an excited state. The excited state is unstable and the atoms return to the ground state by emission of a photon (spontaneous emission), which can be in any direction.

A laser beam on the other hand, which is generated by a device, consists of photons which are of the same wavelength (monochromatic), coherent (all components of the waveform are in phase) and collimated (very little beam divergence). The basic laser generator consists of three components: (1) an active or lasing medium, (2) an optical chamber or resonator and (3) an energizing source (Figure 30.1).

When energy is pumped into the lasing medium, it is absorbed by the individual atoms in the medium, which are elevated to an excited state (stimulated absorption). The photons released as these atoms try to revert to a ground state, collides with other excited atoms which are forced to emit an identical photon (stimulated emission), which are of the same wavelength, direction and phase. The stimulated photons produced are reflected back and forth by parallel mirrors in the optical chamber and the number of photons amplified by each reflection (amplification). When more atoms achieve an excited state – 'population inversion' occurs. The front of the output mirror is designed to be partially reflective and allows a small percentage of the energy to be emitted as a laser beam. This beam is further passed through a series of focusing lens to reduce its diameter and increase its intensity and energy to make it suitable for clinical applications.

The differing types of laser now available are determined by the active (lasing) medium producing the beam (Table 30.1). The lasers used in maxillofacial surgery are often delivered to the tissues via optical cables or through mirrors in an articulated arm and is dependent on the wavelength and power of the laser beam. Carbon dioxide (CO_2) laser is traditionally delivered with an articulated arm and others such as neodymium:yttrium-aluminium-garnet (Nd:YAG) and potassium-titanyl-phosphate (KTP) are delivered by fibre optic cables.

LASER–TISSUE INTERACTIONS

The effect of laser on the tissue is principally dependant on its wavelength, power and delivery sequence in addition to the particular characteristics of the tissues. The outcome of these interactions is due to thermal (coagulation, vaporization, carbonization and ignition) and non-thermal (photomechanical, photochemical and photoablative) events. Photothermal effects are due to the production of heat from the absorption of laser energy; photochemical effects are due to changes in the chemical composition of the tissue resulting from the absorption of laser light and photomechanical effects results from the target area being mechanically destroyed by laser absorption.

Selective photothermolysis[1] is the ability to achieve temperature-mediated localized injury to the target tissue through a specific chromophore, while minimizing damage to the surrounding tissue and is dependant on the use of a laser with an appropriate wavelength, energy fluence and pulse duration. Thermal relaxation time is defined as the time required for a given heated tissue to lose 50% of its heat through diffusion and therefore significant thermal diffusion (thermal damage) can be minimized if the duration of the laser pulse is shorter than the thermal relaxation time of the target tissue. The laser beam can be delivered as a continuous wave, pulsed wave (nanoseconds to seconds) or Q-switched (very fast pulses 10^{-9} seconds).

Therefore, for proper selective thermolysis to occur, the target tissue (through its chromophores) must possess greater optical absorption than the non-targeted surrounding tissue and the laser of choice must have pulse duration shorter than the thermal relaxation time of the target tissue. Further, the power, focus and duration that the beam dwells in a particular spot also influence the tissue effects (focused beam – incision, defocused beam – vaporize at high power, coagulate at low power). The wavelengths, target chromophores and principle uses of the commonly used lasers in maxillofacial surgery are highlighted in Table 30.2.

In general, there is very little inflammation associated with laser wounds with resultant decrease in pain and scarring. This is thought to be due to the denaturation of proteins, including the inflammatory mediators, with subsequent underestimation by the body of the damage caused by the

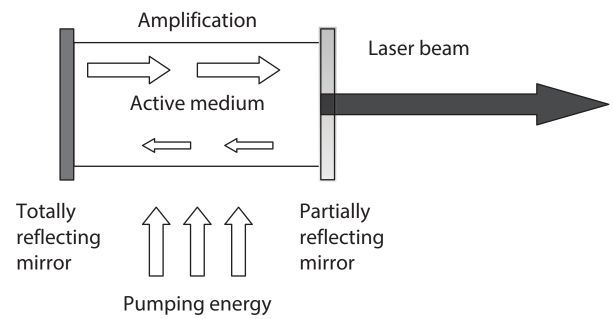

Figure 30.1 Laser generator.

Table 30.1 Types of laser.

Gas lasers	
	Carbon dioxide (CO_2)
	Argon (Ar)
	Helium–neon (He–Ne)
Solid/crystal lasers	
	Neodymium:yttrium-aluminium-garnet (Nd:YAG)
	Ruby
	Alexandrite
	Potassium-titanyl-phosphate (KTP)
Excimer lasers	
	(Mix of rare gas and active elements)
	Argon fluoride (ArFl)
Dye lasers	
	Organic dye in solvent

Table 30.2 Laser characteristics and common clinical uses.

Laser type	Wavelength (nm)	Target chromophore	Clinical uses
CO_2	10,600	Water	Cutting, vaporization, skin resurfacing, scar revision
Er:YAG	2,940	Water	Skin resurfacing, scar revision
Nd:YAG	1,064	Oxyhaemoglobin, melanin, black, yellow, red, orange pigment	Vascular lesions (venous malformations), tattoos, pigmented lesions, hair removal
Alexandrite	755	Melanin, black, blue, green pigment	Tattoos, hair removal, pigmented lesions
Ruby	694	Melanin, black, blue, green pigment	Tattoos, hair removal, pigmented lesions
Pulsed dye laser (PDL)	577–595	Oxyhaemoglobin, melanin, yellow, red, orange pigment	Vascular lesions (capillary, venous malformations), pigmented lesions, tattoos, scar revision
KTP	532	Oxyhaemoglobin	Vascular lesions (venous malformations)

laser. The denatured collagen is also partly responsible for the heamostasis obtained following CO_2 laser wounds, though this is restricted to vessels less than 0.5 mm in diameter.

PRACTICAL LASER SAFETY

Parameters to consider

Wavelength: Its selection is principally influenced by the target chromophere and the intended depth of penetration (determined by the location of the target chromophere). The shorter the wavelength, the more superficial the penetration and longer the wavelength, the deeper the penetration.

Power and spot size: Power and spot size determines power density and influences the energy and heat delivered to the target tissue. For a given power output, decreasing the spot size will increase the energy delivered to a unit target area (like a magnifying glass concentrating sunlight on a target). Decreasing the spot size will, however, reduce the depth of penetration of the laser. As a general rule, when the spot size is halved, the energy output will have to be doubled to create an effect at the same treatment depth. The principal determinant of treatment depth is the wavelength, regardless of power or spot size.

Pulse width: It is the delivery/exposure time of the laser to the target tissue. Its selection is influenced by the volume and thermal relaxation time of the target tissue. The ideal pulse width is half the thermal relaxation time of the target tissue.

Cooling: Laser therapy aims to maximize and restrict thermal damage to the target chromophore, while minimizing damage to the superficial epidermis. Selective cooling of the superficial skin layers can reduce the undesirable thermal injury. The two commonly used cooling modalities are sapphire plate contact cooling and cryogen spray cooling systems. The contact system works by recirculating chilled water (4°C) around a transparent medium that is kept in direct contact with the target tissue for less than 2 seconds and removed manually. The selective epidermal cooling or dynamic cooling uses the Freon substitute (cryogen) as the conductive medium and is delivered in spurts of spray directed over the treated area of a fixed diameter. The droplet temperature is variable, but usually set clinically between 45°C and 55°C.

Operational and environmental safety

Lasers are safe if used appropriately, though the risks to patient and the staff can be significant if used improperly. The safety of lasers is classified according to its effect on the skin or cornea and is based on the maximum permissible exposure (MPE) levels. Class I is the safest and Class IV is the highest and most dangerous; medical lasers are Class IV. The clinician using the laser is responsible for the safety of the patient and the staff. Local policies should, however, be in place to allow use of lasers by only trained clinicians, in a safe laser environment staffed by a trained support team. These operational aspects are often overseen by laser protection supervisors and laser protection advisors in the hospital.

The clinician should demonstrate appropriate training, understanding and experience with lasers in addition to being aware of the local safety guidelines. The supporting team, which usually includes a senior nurse prepares the theatre, checks and starts up the laser and assists with the setting during its use. The key to laser machine is often kept by this person, who keeps it with their house key to ensure that it is not left near the laser machine. The number of keys in circulation is also strictly controlled.

Safe environment involves the creation of a laser light-tight envelope to the theatre in addition to provision of a regularly serviced and inspected laser machine. The access should be limited to essential personnel instructed in laser safety and doors should be locked and all windows and ventilation pathways covered with shutters. Clear warning with illuminated signs should highlight that a laser procedure is in progress and local safety rules apply. These signs are usually interlocked with the electrical supply of the laser machine and illuminate automatically when the power is switched on. Some hospitals have interlocks on the doors, which inhibit laser emission if the door is opened and interrupts clinical procedures. In these instances, it would be sensible to have additional door locks to prevent interlocks cutting the laser emission.

Clinical staff and patient protection

All the staff in the theatre including the surgeon should wear eye protection designed for the particular laser in use. These are designed to provide protection from accidental exposure and are not intended to allow direct viewing of the laser beam.

It is essential that the hand piece is not waved around carelessly, when the laser is switched on. When active, it should only be aimed at the operation site and all other times should be switched to the safe standby mode. The support staff in charge of the machine should always keep an eye on the clinician and should switch to standby mode if the laser is being pointed away from the operative site. Mirrors and highly polished surfaces should be excluded from the operative site.

The key areas of patient safety in maxillofacial surgery relate to the airway, eyes and sites adjacent to the target. Though it is rare for explosive gases to be used in anesthesia; nowadays, it is good practice to discuss this with the anesthetist. There are, however, inflammable combination of agents such as nitrous oxide and oxygen used regularly and it is vitally important that the laser beam does not penetrate the lumen of the airway or endotracheal tube, with a significant risk of a catastrophic airway fire. There are specially designed armoured laser resistant endotacheal

tubes available, which are often placed per orally. This can restrict access for treatment in the mouth, and in these instances, a nasal tube can be used with additional protection with a metal foil till the nose and saline soaked gauze throat and post-nasal pack to protect the tube in this area. It is important to be particularly aware of the possibility of perforating the palate and entering the nasal airway and causing damage to the nasal tube in this region. In the same way, a cleft palate is a potential risk and an armoured oral tube would be a better option.

Eye protection is vitally important and depends on the particular procedure being undertaken. Lead corneal protectors are used for procedures involving the eyelids and periorbital areas, whereas special laser safety glasses are used for other procedures. The areas surrounding the operative site are protected by a thick layer of saline-soaked gamgee, in which a small hole can be cut to allow access to the target site.

Laser plumes contain dust, hazardous chemicals and biological agents (bacteria, viral DNA), which can cause potential harm. A laser grade smoke evacuation system (high flow, two-stage filtration, filtration efficiency >99.99%, down to a particle size of 0.05 μm) is therefore essential for scavenging, in addition to wearing surgical masks and gloves.

CLINICAL APPLICATIONS

The common clinical uses of laser are highlighted in Table 30.2 and specific applications are described in detail in other chapters in this book. When a CO_2 laser is used, it is important to check on each occasion that the He–Ne visible light indicator laser and the invisible CO_2 beam coincide. This is done by aiming the He–Ne laser at a target spot on a wooden spatula and firing the CO_2 laser and comparing the target spot with the burn spot. Do not rest your spatula on your lap when you do this.

The CO_2 and erbium lasers are often used for cutaneous resurfacing and the recent advent of computerized pattern generator and scanning capabilities have allowed for large areas to be treated rapidly and safely. CO_2 laser resurfacing has been associated with the reactivation of herpes simplex virus (HSV) causing delayed re-epithelialization and scarring. Antiviral prophylaxis (famciclovir, valacyclovir) should be instituted in this group of patients.

NEWER TECHNOLOGIES

Fractional photothermolysis (Fraxel) works by producing thermal damage to microscopic zones of the epidermis and dermis and therefore it is postulated that following fraxel skin resurfacing, the surrounding normal skin will help in faster healing and less ‘down time’ between treatments.

Intense pulsed light (IPL) is not a laser, but a non-coherent, multi-wavelength light source, in which appropriate filters are placed to produce light with wavelengths ranging from 590 to 1200 nm. It is primarily used for hair removal, pigmentary disorders and non-ablative skin tightening.

Top tips

- Always refer to the local protocols for the use of lasers.
- Careful protection of the patient, operator and other staff is essential.

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SUGGESTED READING

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31

Computer-assisted reconstruction of the facial skeleton

FRANK WILDE and ALEXANDER SCHRAMM

CONTENTS

HISTORICAL OVERVIEW OF COMPUTER-ASSISTED RECONSTRUCTION OF THE FACIAL SKELETON

Computer-assisted surgery of the head and neck dates back to the end of the last century. Three-dimensional (3D) printing with stereolithography was introduced in the 1980s. Since the 1990s, this technique has been increasingly used together with novel techniques for the visualization of 3D computed tomography (CT) data sets for creating patient-specific models for surgical planning and simulation. This approach, however, was both complex and expensive. The introduction of frameless stereotaxy, or in other words intra-operative navigation systems, gave decisive impetus to computer-assisted surgery. Neurosurgeons were the first to use this advanced technology. As early as the mid-1990s, oral and maxillofacial surgeons too recognized the advantages that this novel technique offered and ever since have increasingly used it in their specialty. High costs, initial system inaccuracies and especially the absence of appropriate and easy-to-use software for planning and simulating complex reconstructions were the reasons why this technique was initially used mainly on a case-by-case basis for navigation-assisted tumour resection, for planning and performing osteotomies and for dental implant placement. Further milestones in the workflow of computer-assisted reconstruction of the facial skeleton were reached when appropriate planning and simulation software was developed and implemented at the beginning of this millennium and further improved over the following 10 years. Further progress has been made in data set segmentation and the automatic segmentation of CT data sets, which involves the division of data sets into surgically relevant segments for the generation of virtual templates for facial skeleton reconstruction. In addition, the surface tessellation language (STL) file format allows external objects such as preformed implants to be imported into software platforms. As a result of these advances, navigation is now routinely used in the clinical setting for the computer-assisted reconstruction of the facial skeleton. The implementation of intra-operative 3D imaging and the prefabrication of patient-specific implants, which includes the production of resection, bone-cutting and positioning guides, has further increased the surgeon's options in reconstructing the facial skeleton with computer assistance. All these aspects are included in the workflow of computer-assisted reconstruction of the facial skeleton (Figure 31.1).

DIAGNOSIS AND ANALYSIS

Diagnosis precedes the computer-assisted reconstruction of the facial skeleton and is based on clinical findings and 3D imaging since the usefulness of conventional 2D radiographs

is considerably limited as a result of superimposition. With the exception of panoramic radiographs, which provide a good overview of major anatomical structures and are therefore still useful, 2D images of the facial region (images of the paranasal sinuses, posterior–anterior or lateral images of the skull etc.) are no longer required.

CT, magnetic resonance imaging (MRI) and cone-beam computed tomography (CBCT) are high-resolution imaging modalities that provide 3D morphological information. Since the reconstruction of the facial skeleton requires the visualization of bone structures in great detail, CT and CBCT are currently the only imaging modalities that provide a resolution that is high enough to meet the requirements of facial bone reconstruction.

MRI is particularly suitable for imaging soft tissues and is therefore useful for detecting soft-tissue processes such as soft-tissue tumours or soft-tissue inflammation and for planning the surgical management of these conditions.

A comparison of CT and CBCT reveals that both modalities provide excellent resolution of bone structures and that the effective radiation dose delivered to a patient during a CT examination is generally higher than that resulting from a CBCT scan.

In spite of this, CT must be regarded as the gold standard for primary diagnosis preceding facial skeleton reconstruction and should be preferred to CBCT as the standard imaging modality for the assessment of bone structures since it provides not only excellent resolution of bone structures but, unlike CBCT, also allows soft-tissue structures to be evaluated, especially with the use of contrast media. Retrobulbar haemorrhage can usually not be identified by CBCT alone. Although CT is associated with a higher effective radiation dose, it should be preferred to CBCT especially for the diagnosis and reconstruction planning of tumour diseases, extensive inflammation and severe malformation since these conditions require the assessment of both bone and soft tissues.

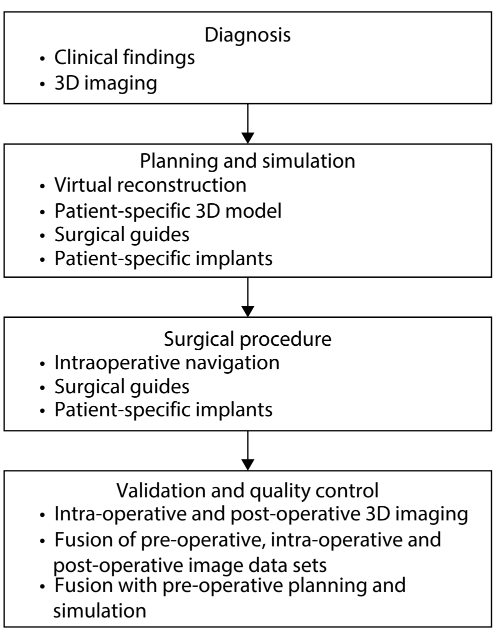


Figure 31.1 Workflow of computer-assisted reconstruction of the facial skeleton.

A combination of CT and positron emission tomography (PET), which is also known as PET-CT, offers further advantages in the diagnosis of tumour diseases. When an appropriate scanning protocol is used and the CT data set is reconstructed with a maximum slice thickness of 1.0 mm, PET-CT images can be used not only for diagnostic purposes but also for planning bone reconstructions so that no additional radiographs are required.

As a rule, not only axial but also coronal and sagittal reconstructions should be generated in order to obtain multiplanar views. Data sets should be reconstructed with a slice thickness not exceeding 2 mm. Nevertheless, a slice thickness of 1 mm or less is recommended since important details may otherwise be visualized with insufficient resolution and accuracy may be compromised by the segmentation of virtually generated 3D objects (orbit, zygomatic bone, mandible etc.) and the interpolation of slices. This can, in particular adversely, affect the accuracy of fit of patient-specific implants and patient-specific surgical guides and can thus have negative effects on the entire reconstruction.

PLANNING AND SIMULATION

Virtual computer-assisted planning and simulation of a facial reconstruction is performed on the basis of pre-operative 3D data sets to increase the predictability of the desired outcome and the safety of the surgical procedure. Reconstruction is planned using appropriate planning software that allows any number and many different types of simulations to be performed without a loss of information and allows 2D and 3D images to be displayed in any plane. Different data sets can be combined by semi-automatic fusion and can then be used for a precise pre-operative analysis of images from different imaging modalities and for reliable intra-operative and post-operative quality control.

The objective of surgical planning is to create a virtual model that matches the desired outcome of surgery. Planning software that has been developed for this purpose allows for threshold-based segmentation and/or even atlas-based automatic segmentation during the process of creating such a virtual model. In addition, it should enable users to mirror parts of a data set and to freely move, rotate and modify the generated virtual models in a rapid and easy way.

STL data sets of 3D bodies (dental implants, titanium mesh structures etc.) can be imported into planning software so that standard implants, anatomically

preformed implants and patient-specific implants can be virtually positioned in the patient data set pre-operatively and their shape, size and fit can be assessed (Figure 31.2).

STL data sets can be exported so that virtually generated models or reconstructions can be produced by a 3D printer and thus allow patient-specific models to be created. Such models can be used to adapt and pre-operatively bend patient-specific titanium implants such as mandibular reconstruction plates or titanium mesh for midface reconstruction (Figure 31.3).

The next step of computer-assisted facial skeleton reconstruction is to process virtual reconstruction STL data sets using computer-aided design (CAD) software for planning patient-specific implants and to directly produce these implants using computer-aided manufacturing (CAM) techniques (Figure 31.4). This process does not require the fabrication of models.

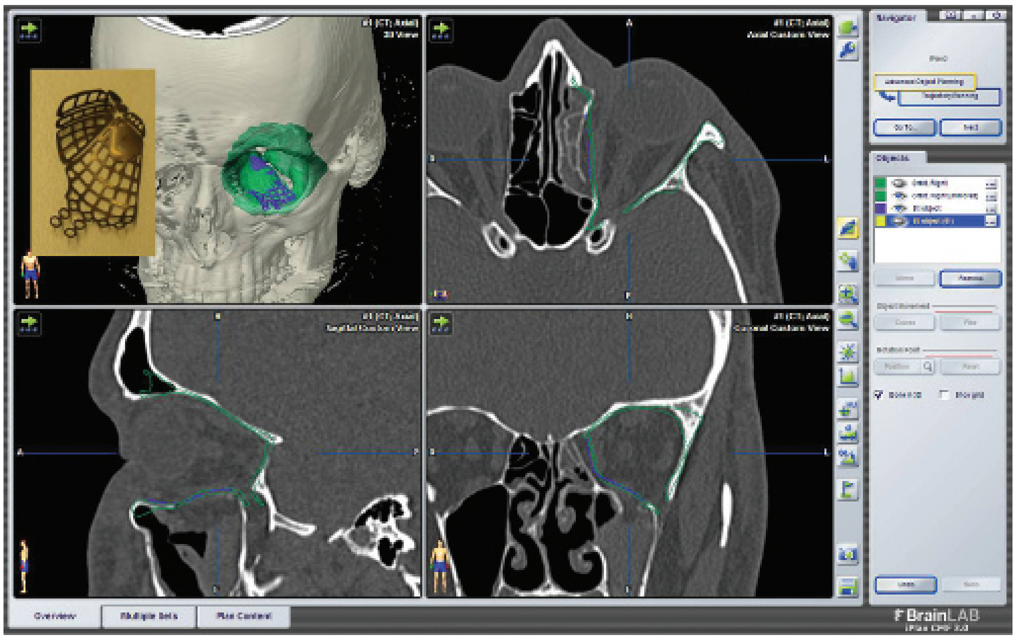
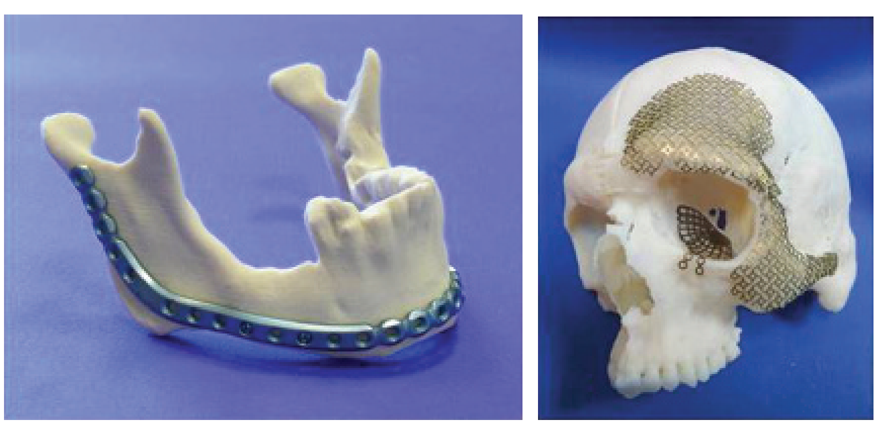


Figure 31.2 Virtual orbital wall reconstruction using iPlan CMF 3.0 (BrainLAB®). The blue object (top right) is a virtual (anatomical preformed) titanium mesh (DePuy Synthes®). The green contour shows the virtual template for the planned reconstruction. The template was created by automatic segmentation and mirroring of the unaffected side.



(a) (b)

Figure 31.3 (a) Patient-specific standard implants preformed using three-dimensional (3D) models. Patient-specific mandibular model with a manually preformed mandibular reconstruction plate. (b) Virtually reconstructed patient-specific skull model with manually preformed titanium mesh for the secondary reconstruction of the facial skeleton.

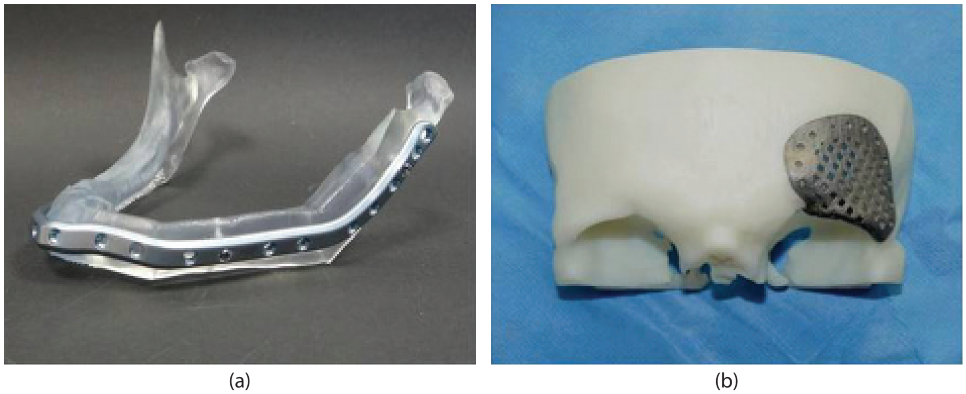


Figure 31.4 Patient-specific computer-aided design (CAD)/computer-aided manufacturing (CAM)–fabricated implants. (a) Computerized numerical control (CNC)–milled patient-specific mandibular reconstruction plate for mandibular reconstruction with a plate and a fibula flap and a simulation model made of polyamide (DePuy Synthes®). (b) Patient-specific titanium implant made by selective laser melting (SLM) for the reconstruction of the facial skeleton and the braincase (KLS Martin®).

COMPUTER-ASSISTED RECONSTRUCTION OF THE MIDFACE

Introduction

During the surgical procedure, surgeons have the difficult task of transferring the result of virtual computer-assisted planning to the surgical site as accurately as possible. For this purpose, they can use or combine a variety of different methods, depending on the complexity of the task.

Intra-operative navigation

Today, intra-operative navigation is an integral part of computer-assisted facial skeleton reconstruction.

Modern infrared-based navigation systems use optical instruments to emit light waves produced by light-emitting diodes (LEDs) that are mounted on the system's camera (indirect systems). These light waves are reflected back to the camera of the navigation system by reflective spheres attached to the instrument (Figure 31.5). The light waves that are reflected by the instrument and detected by the camera system are used to calculate the precise location of the instrument in space, which is then optically displayed on the screen of the navigation system.

At the beginning of the surgical procedure, the patient on the operating table must be 'fused' with the image data set that is displayed on the screen. This process is known as referencing and is based on reference points that must be clearly identifiable and reproducible both on the patient and in the image data set.

Furthermore, the patient's position must be permanently registered since patient movements during surgery cannot be prevented or may even be necessary during the procedure. This is best accomplished by using a star-shaped reference array that is attached to the patient's head

Figure 31.5 Intra-operative setup of an indirect navigation system ([a], camera with integrated LEDs; [b] screen; *, pointer with two reflective spheres; +, reference array with three reflective spheres attached to the calvaria). The yellow lines represent the light waves that are emitted by the camera system and reflected back to the camera system by the reflective spheres of the referencing system (patient tracking). The red lines represent the light waves that are emitted by the camera system and reflected back to the camera system by the reflective spheres of the pointer (instrument tracking).

and allows the navigation system to register all patient movements without limiting head mobility. When a reference array is used, the LEDs that are mounted on the camera of the navigation system emit light waves that are reflected back by the reference array affixed to the patient's head. These waves are detected by the camera and processed by the navigation system (Figure 31.5).

Other fixation methods such as a head strap are associated with a loss of accuracy. Alternatively, the reference array can be secured to a Mayfield clamp. This technique

provides accuracy similar to that of direct skull fixation but does not offer intra-operative mobility of the patient's head.

The accuracy of infrared-based navigation systems is influenced by several factors. The widest range of inaccuracies is associated with the referencing method used. Surgical applications require a standard accuracy of 2 mm. Such a level of accuracy can be reliably achieved by bone-anchored registration points such as screw markers (mini-screws) that are inserted prior to the acquisition of the planning data set. The insertion of mini-screws in the region of the anterior calvaria, for example, can be recommended for this purpose (Figure 31.6a). An alternative non-invasive approach is the use of a maxillary splint and mini-screws (Figure 31.6b) which are attached to the splint by polymerization. Reliability can be increased by combining this method with bone-anchored registration points. As a rule, when reference points are selected or placed, their centre should be located in the surgical field. In addition, accuracy can be improved by using widely spread reference points.

Further methods of registration include the use of anatomical bone landmarks, skin surface matching and skin fiducials, which are registration points that are glued to the patient's skin. Anatomical landmarks have the disadvantage that a sufficient number of landmarks must be identifiable in an accurate and reproducible manner during the surgical procedure. The use of skin surface matching or skin fiducials too is associated with difficulties. One major disadvantage is that imaging must be repeated in the event of changes to the soft-tissue envelope, which, for example, occur when swelling develops or subsides or when surgery is performed. For this reason, these registration techniques are not suitable for facial skeleton reconstruction.

Once the aforementioned technical requirements are met, the position of the pointer or tip of the pointer can be visualized in the data set on the screen of the navigation system. This enables surgeons to verify the realignment of bone fragments and the position and fit of inserted implants during surgery and to make any necessary changes without patient exposure to ionizing radiation. In this process, the virtual reconstruction that has been made during the planning phase serves as an intra-operative template that helps surgeons align bone fragments and/or place implants.

Intra-operative imaging

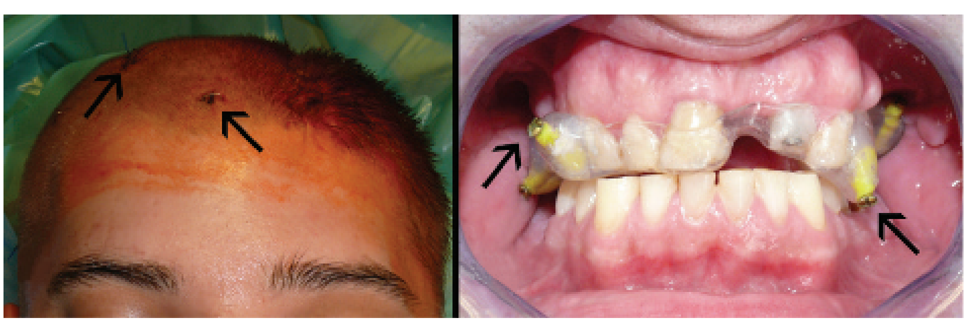
Following the completion of a reconstruction procedure, surgical outcome is validated in three dimensions. If possible, such a validation should be performed during the surgical procedure immediately after reconstruction. This applies in particular to midface and orbital reconstructions and, where appropriate, to the reduction and fixation of mandibular condyle fractures.

This allows necessary modifications such as incorrect positions of bone fragments and implants to be made during the surgical procedure.

In general, ultrasonography, MRI, CT and CBCT are imaging modalities that can be used during surgery.

Intra-operative imaging for facial skeleton reconstruction, however, must meet a number of special requirements as follows:

- Sufficient resolution, especially for imaging the thin bone structures of the midface and orbits and the inserted implants
- Rapid availability in the operating room
- Short-scan time
- Fast and safe use by surgeons and assistant personnel
- Multiplanar imaging (in the axial, coronal and sagittal planes)
- Export of Digital Imaging and Communications in Medicine (DICOM) data for the fusion of intra-operative images with pre-operative images or pre-operative planning
- Data storage on the Picture Archiving and Communication System (PACS) of the medical facility for meeting the requirement of archiving intra-operative image data sets



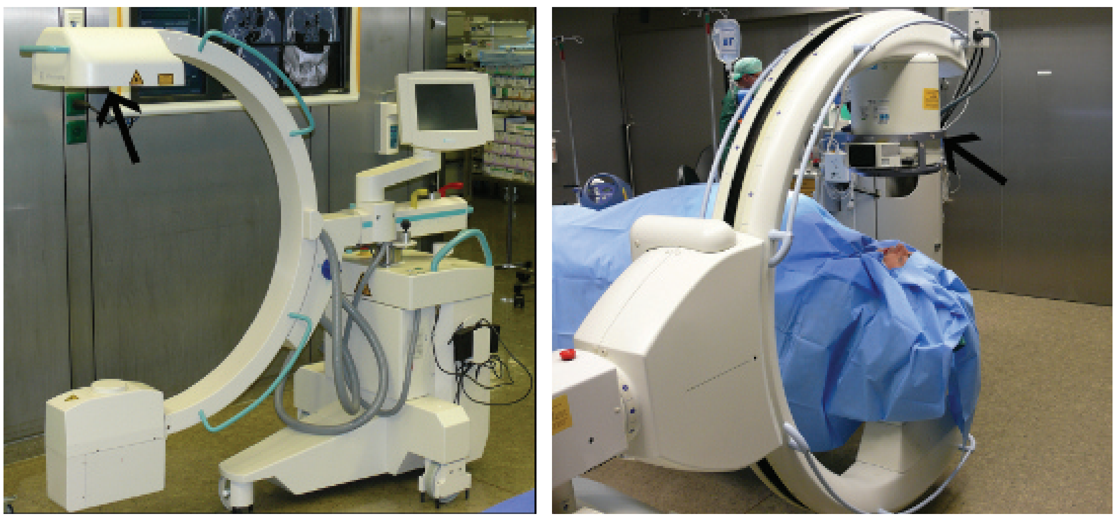
(a) (b)

Figure 31.6 Referencing for intra-operative navigation. (a) Invasive referencing with mini-screws inserted into the calvaria under local anaesthesia before computed tomography (CT). Sites of incision are marked by black arrows. (b) Non-invasive referencing using a maxillary splint and four titanium mini-screws (arrows) fixed to the splint by polymerization.

CBCT offers a number of advantages that make this modality superior to others in meeting the aforementioned requirements. CBCT systems are available as mobile, ceiling-suspended or floor-mounted 3D C-arm systems for use in the operating room (Figures 31.7 and 37.8) or as small compact CBCT systems for intra-operative use (e.g. Xoran® x-CAT).

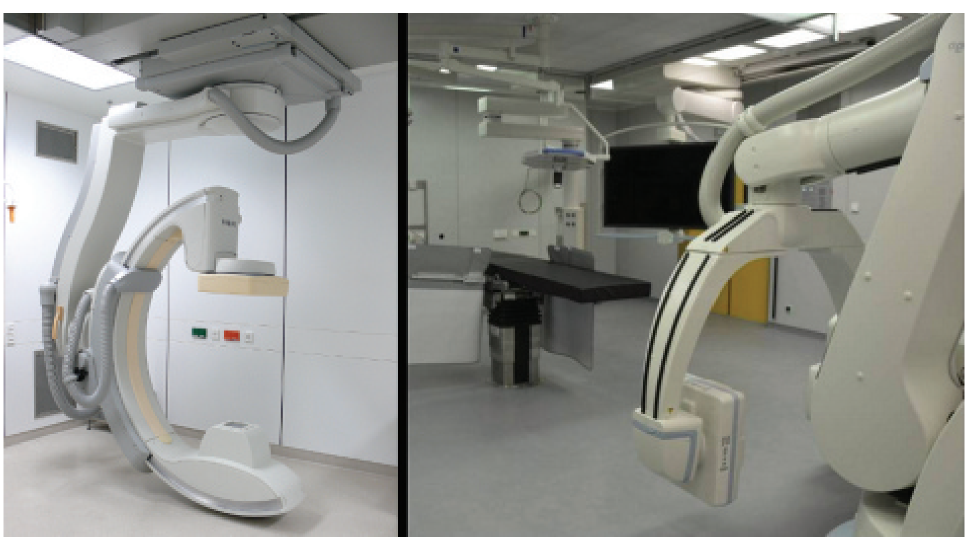
The systems consist of a motor-driven isocentric C-arm that is rotated 180° around the patient. They produce image series for multiplanar imaging in the axial, coronal and sagittal planes and thus allow hard tissues to be imaged during surgery. Soft tissues, however, cannot be assessed. The radiation dose depends on the system used, and in particular on tube output, image repetition rate and exposure time. Although there are no comparative studies in the literature, the dose of radiation that is applied during a single rotation of the C-arm can be assumed to be lower than that from a comparable conventional CT scan of the facial skeleton.

The images that are produced by these systems are of such quality that additional post-operative imaging is usually not required. The use of a mobile 3D C-arm can thus be regarded as the current standard intra-operative imaging modality in facial skeleton reconstruction.



(a) (b)

Figure 31.7 Mobile 3D C-arm systems. (a) Vario (FD) 3D with a flat panel detector (black arrow) (Ziehm®). (b) Arcadis Orbic 3D with an x-ray image intensifier and a tracking device for intra-operative navigation (black arrow) (Siemens®).



(a) (b)

Figure 31.8 Fixed 3D C-arm systems. (a) Ceiling-suspended 3D C-arm system (Allura Xper FD series, Philips®). (b) Hybrid operating room with a system that combines a floor-mounted robotic arm and a C-arm imaging system (Artis Zeego, Siemens®).

Applications of computer-assisted midface reconstruction

Isolated fractures of the zygomatic arch

Computer-assisted surgery with intra-operative imaging allows surgeons to increasingly use or to revive the use of minimally invasive techniques without decreasing the predictability of the outcome of reduction procedures. This, for example, applies to the transcutaneous reduction of the zygomatic bone and zygomatic arch using a traction hook. Following a stab incision, the hook is inserted below the zygomatic bone or zygomatic arch for closed reduction of the fracture. Immediately after the surgical intervention, reduction is verified using a 3D C-arm in the operating room. If necessary, reduction can be directly corrected and unstable fractures can be managed by open reduction and fixation (Figure 31.9).

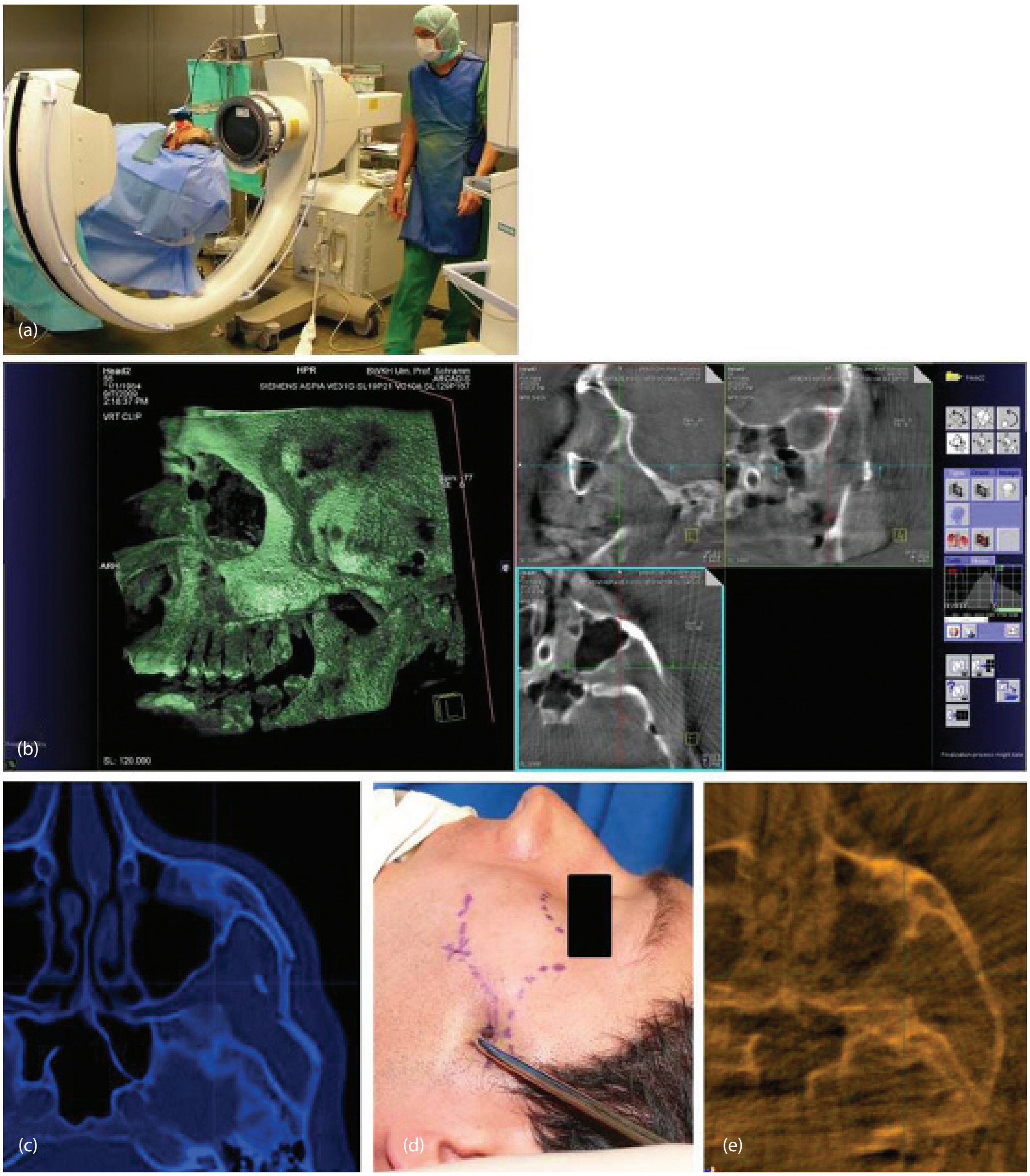


Figure 31.9 Closed zygomatic bone/zygomatic arch reduction using intra-operative 3D C-arm imaging. After closed zygomatic arch reduction (d), the 3D C-arm (a) rotates 180° around the patient's head. (b) Multiplanar (right) data set representation and 3D reconstruction allow for an accurate intra-operative analysis of the reduction of a lateral midface fracture and an assessment of the need for orbital wall treatment after zygomatic bone and zygomatic arch reduction. (c) Pre-operative CT shows a depressed fracture of the left zygomatic arch. (d) Reduction by traction hook after transcutaneous stab incision. The bony contours of the zygomatic bone and zygomatic arch as well as the locations of stab incisions for traction-hook reduction are marked. (e) Following traction-hook reduction, intra-operative imaging shows the anatomically correct position of bone fragments in the region of the zygomatic arch.

Fractures of the zygomatico-orbital complex

Fractures of the zygomatico-orbital complex are associated not only with zygomatic bone fractures but often also with displaced fractures in the region of the orbital floor. In such cases, the question is what degree of orbital floor displacement requires surgical reconstruction in addition to a reduction of the zygomatic bone fracture. Surgical reconstruction involves an intra-orbital procedure with increased morbidity. For this reason, a surgical reconstruction of the orbital floor should only be performed if absolutely necessary. Since the zygomatic bone forms part of the orbital floor, a reduction of the zygomatic bone – including a closed reduction of the orbital floor – is sufficient in many cases. After zygomatic bone reduction and especially after a closed reduction, it is still unclear during surgery whether zygomatic bone reduction has also resulted in a sufficient reduction of the orbital floor or whether additional orbital reconstruction is required. Intra-operative 3D imaging allows surgeons to rapidly assess the condition of the orbit and to avoid unnecessary explorations and orbital reconstructions (Figure 31.10).

Orbital wall fractures

Fractures of the orbital walls (medial wall or orbital floor) should receive delayed primary care within the first 2 weeks and after resolution of the swelling. Especially, orbital wall fractures with involvement of the junction between the posterior orbital floor and the medial orbital wall and blow-out fractures of the orbital wall are associated with an increased risk of malposition of reconstruction material. This is attributable to the complex and difficult preparation procedure and usually limited visibility with haemorrhage and protrusion of orbital tissue. A biologically inadequate reconstruction of the orbit or entrapment of orbital tissue can lead to persistent globe displacement that may result in enophthalmos or exophthalmos and/or can lead to functional deficits such as diplopia or strabismus. Compared with primary reconstructions, secondary reconstructions are associated with a higher complication rate and do not always lead to the desired functional outcome despite anatomically adequate repair. For this reason, primary reconstruction should be preferred. Among the materials used for reconstruction,

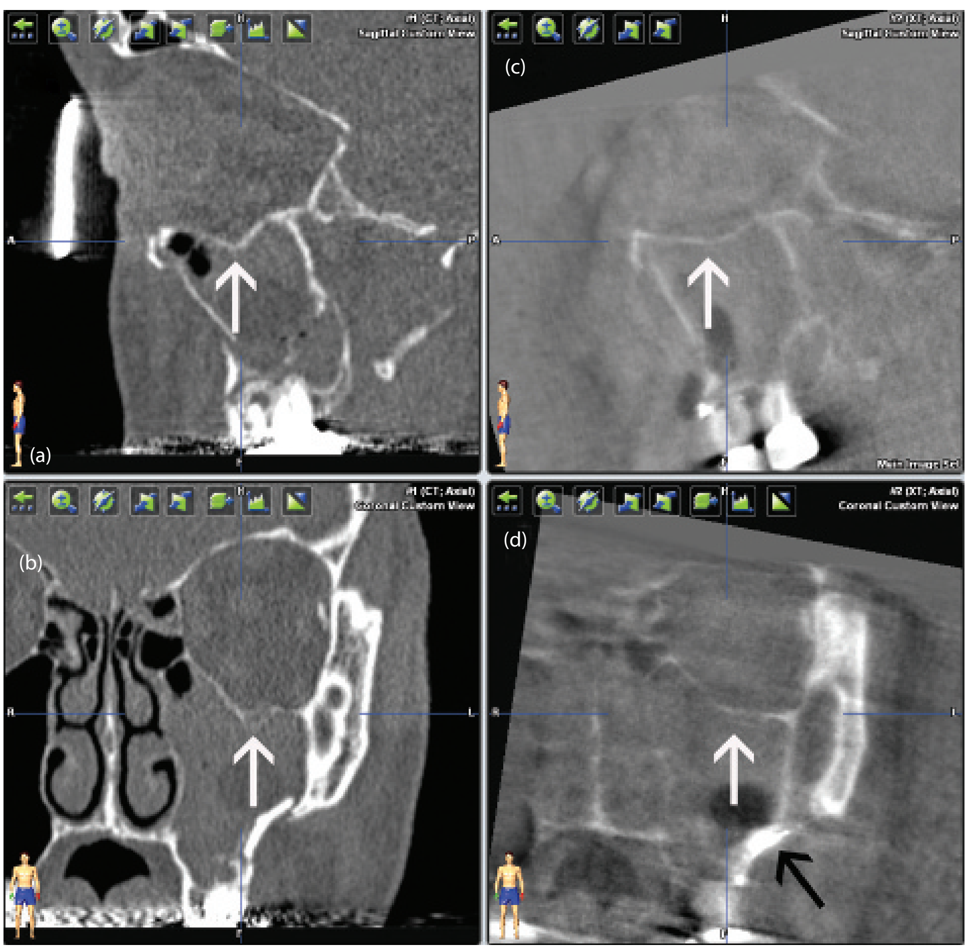


Figure 31.10 Fusion of pre-operative CT scans and intra-operative 3D C-arm images after the reduction of a zygomatico-orbital complex fracture. (a and b) Pre-operative CT scans of a displaced fracture of the orbital floor (white arrows). (c and d) Intrao-perative images after zygomatic bone reduction and fixation on the zygomatico-alveolar crest (black arrow). The images show an anatomically correct position of the orbital floor (white arrows). There is no need for open exploration and further management of the orbital floor.

alloplastic materials such as titanium mesh are increasingly preferred to autologous bone grafts since they can be adapted to the patient's anatomy, they are non-absorbable and therefore offer more predictable results; they cause less donor site morbidity.

For this reason, the first step in the management of complex orbital wall fractures is virtual reconstruction by automatic segmentation of the CT data set into anatomical and surgical structures (iPlan CMF 3.0, BrainLAB®, Feldkirchen, Germany) (Figure 31.11a). Before surgery, a virtual template for orbital reconstruction can be created either by mirroring the unaffected side in the case of unilateral fractures or by using free-form segments in the case of bilateral fractures with subsequent alignment of segmentation (Figure 31.11b). Anatomically preformed titanium implants (DePuy/Synthes®, Zuchwil, Switzerland) or patient-specific titanium implants manufactured by selective laser melting (SLM) (KLS Martin®, Tuttlingen, Germany) can be virtually placed before surgery in order to assess the accuracy of fit (Figures 31.11b and 31.12c,d). A navigation system can then be used to verify the alignment of bone fragments after reduction and the position and shape of the inserted implants. The tip of the pointer is placed on the implant or bone and the position of the pointer tip shows the current position of the structure of interest (Figure 31.11c). This enables surgeons to verify reduction as well as the position and accuracy of fit of implants and to make any necessary corrections. Intra-operative 3D imaging is then performed as a final assessment of the procedure. Details of radiological images are sufficient to allow reconstruction results to be accurately validated on the basis of intra-operative data sets that are fused with pre-operative data sets and simulations (Figures 31.11d and 12e,f). Whereas previously orbital floor and medial orbital wall reconstructions required a coronal incision, the combined use of patient-specific or anatomically preformed implants, intra-operative navigation and imaging now enables surgeons to perform even extensive reconstructions of the orbital floor and medial orbital wall via a transconjunctival approach and thus to avoid visible scars.

Secondary reconstruction of the orbit and midface

Secondary reconstructions are extremely challenging for surgeons because of the presence of soft-tissue atrophy and scarring. The complex anatomy of the orbit and the peri-orbital region often complicate functional and aesthetic reconstruction with autologous bone. Reconstruction using alloplastic materials (preferably titanium) is much easier since these materials can be combined with autologous bone grafts (e.g. calvarial bone) or vascularized soft-tissue or bone flaps. Computer-assisted simulation and planning (Figure 31.13a through 13c) allows bone reconstructions to be virtually planned in detail before surgery and to be exported as an STL data set (iPlan CMF 3.0, BrainLAB®, Feldkirchen, Germany). A patient-specific 3D plastic model can then be printed on the basis of the STL data set (Figure 31.13d) and patient-specific reconstruction can be prepared using standard implants and standard mesh structures (Figure 31.13e). Alternatively or additionally, such patient-specific implants can also be manufactured industrially using polyether ether ketone (PEEK), ceramics or titanium (Figure 31.13f). These pre-operatively manufactured implants are placed intra-operatively using a pointer-based navigation system (Figure 31.13g). 3D imaging allows the position of an implant to be verified during surgery (Figure 31.13h) and after surgery (Figure 31.13i).

COMPUTER-ASSISTED RECONSTRUCTION OF THE MANDIBLE

Introduction

The human mandible plays a key role in masticating food, swallowing and speaking and supports the tongue, which keeps the airways clear. In addition, it is important for the harmonious appearance of the face. In diseases of the oral cavity such as carcinomas, osteoradionecrosis, osteomyelitis or medication-related necrosis of the lower jaw, the surgical removal of a portion of the mandible, and thus a loss of mandibular continuity are inevitable in many cases. The rehabilitation of the mandibular contour, the restoration of occlusion, and the correct position of the condyles in the glenoid fossae are crucial for providing the patient with adequate masticatory function and an aesthetically satisfying result. Two methods are primarily used to reconstruct mandibular continuity defects: (1) alloplastic mandibular reconstruction using mandibular reconstruction plates and secondary bone reconstruction of the defect zone after a relapse-free interval and (2) primary mandibular bone reconstruction following resection in combination with reconstruction plates or miniplates.

Patient-specific implants are used for computer-assisted mandibular reconstruction. They can be combined with patient-specific resection, cutting and positioning guides.

When patient-specific implants or reconstruction plates are used, it is difficult for surgeons to position them on the mandible according to planning. Without the use of surgical guides, it is also often impossible to adequately osteotomize microvascular bone segments and to fixate them to a plate as planned. Patient-specific surgical guides thus play the role of an interface between the virtual and the real world. For this reason, their design and accuracy are of crucial importance for an exact transfer of virtual reconstruction to the patient.

Apart from the basic distinction between primary alloplastic and primary bone reconstruction, the following types of procedures can be distinguished:

- The simplest procedure involves the use of a standard implant that is manually bent in accordance with a patient-specific model and fixated to the mandible in a standard surgical procedure.

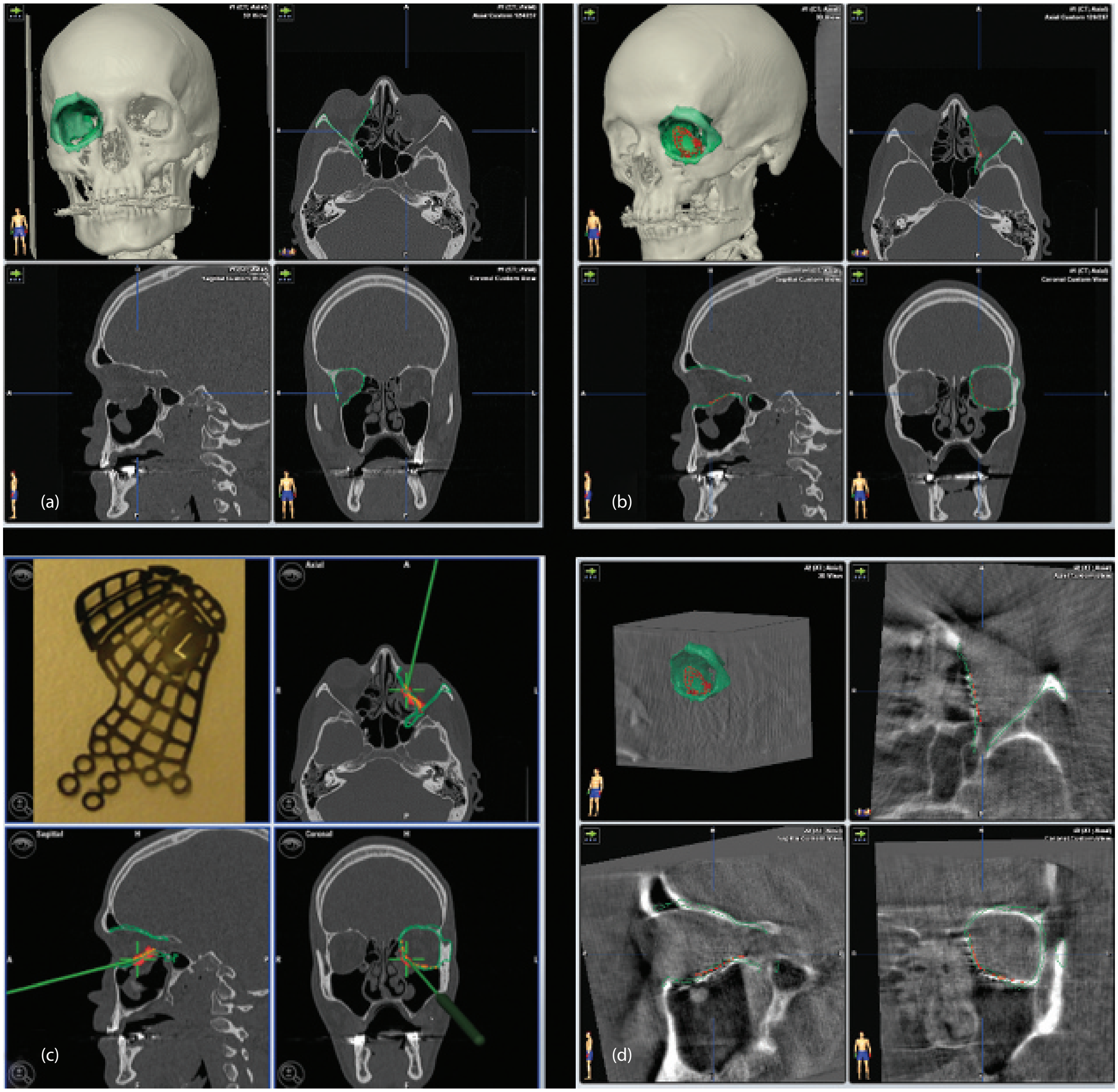


Figure 31.11 Computer-assisted primary reconstruction of the left orbit using an anatomically preformed implant. (a) Multiplanar view of the virtual planning and creation of a template for orbital wall reconstruction by means of automatic segmentation of the unaffected right orbit using iPlan CMF 3.0 (BrainLAB®) (green contour lines). (b) Multiplanar view of the virtual reconstruction of the left orbit by means of mirroring the segmentation of the unaffected side (green contour lines) and virtual placement of an anatomically preformed orbital implant (red contour lines). The virtual placement of the anatomically preformed titanium implant allows surgeons to verify the size and accuracy of fit of the orbital implant. During surgery, implant placement (red contour lines) is performed according to the virtual reconstruction of the orbit (green contour lines) or the virtual placement of the implant. (c) Multiplanar view of the navigation-assisted placement of an anatomically preformed orbital implant (c: top left) (DePuySynthes®). The green contour line shows the virtual reconstruction of the orbit (analogous to the green contour line in [b] and [d]). During the surgical procedure, the red contour line displays the surface of the orbital implant inserted on the basis of implant surface data provided by the navigation tool. The orange contour line shows the virtually planned orbital implant on the screen of the navigation system (analogous to the red contour line in [b] and [d]). Multiplanar view of intra-operative 3D imaging with superimposition of virtual planning. The green contour line represents the virtual reconstruction (analogous to [b] and [c]) and the red contour line shows the virtually placed orbital implant (analogous to [b]). The image shows good fit of the radio-opaque implant in accordance with virtual planning.

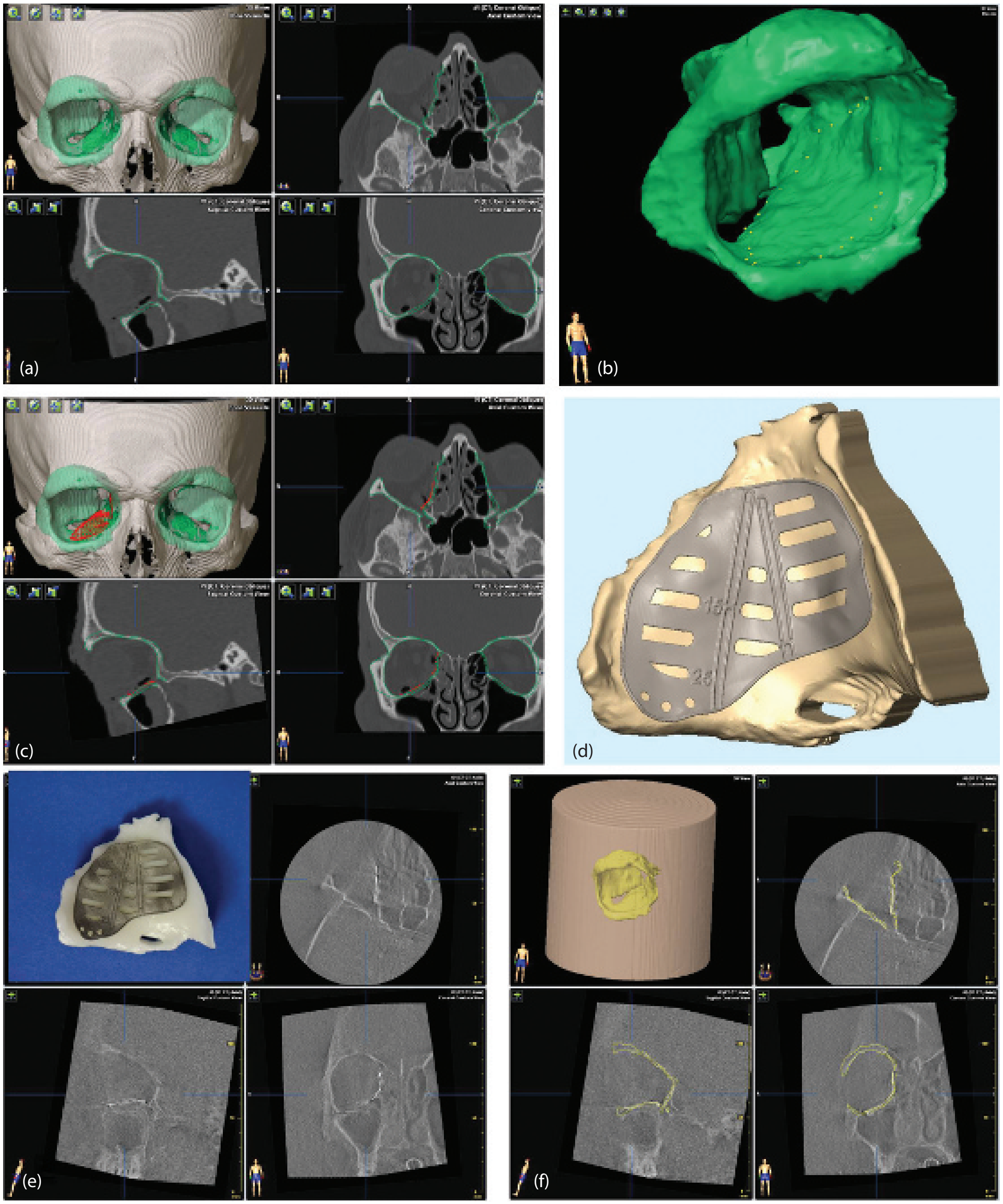


Figure 31.12 Computer-assisted primary reconstruction of the left orbit with a patient-specific implant manufactured by SLM (KLS Martin®). (a) Multiplanar view of the virtual planning and creation of a template for orbital wall reconstruction by means of automatic segmentation and mirroring of the unaffected left orbit using iPlan CMF 3.0 (BrainLAB®) (green contour lines). (b) Virtual template of the right orbit for the simulation and determination of the size of the patient-specific implant (yellow dots). (c) Multiplanar view of the virtual reconstruction with a virtually placed patient-specific implant that was imported into the left orbit as an STL data set after industrial planning (red contour line). Virtual implant placement allows the accuracy of fit to be verified before the implant is manufactured. During surgery, implant placement (red contour lines) is performed according to the virtual reconstruction of the orbit (green contour lines) or the virtual placement of the implant. (d) CAD of the patient-specific implant. The implant corresponds to the implant that was virtually placed as an STL data set in [c]. (e) Multiplanar view of intra-operative 3D imaging. The top left image shows the patient-specific implant after placement. (f) Multiplanar view of intra-operative 3D imaging with superimposition of virtual planning. The yellow contour line shows the virtual reconstruction (analogous to [a], [b] and [c]). The image shows good fit of the radio-opaque implant in accordance with virtual planning.

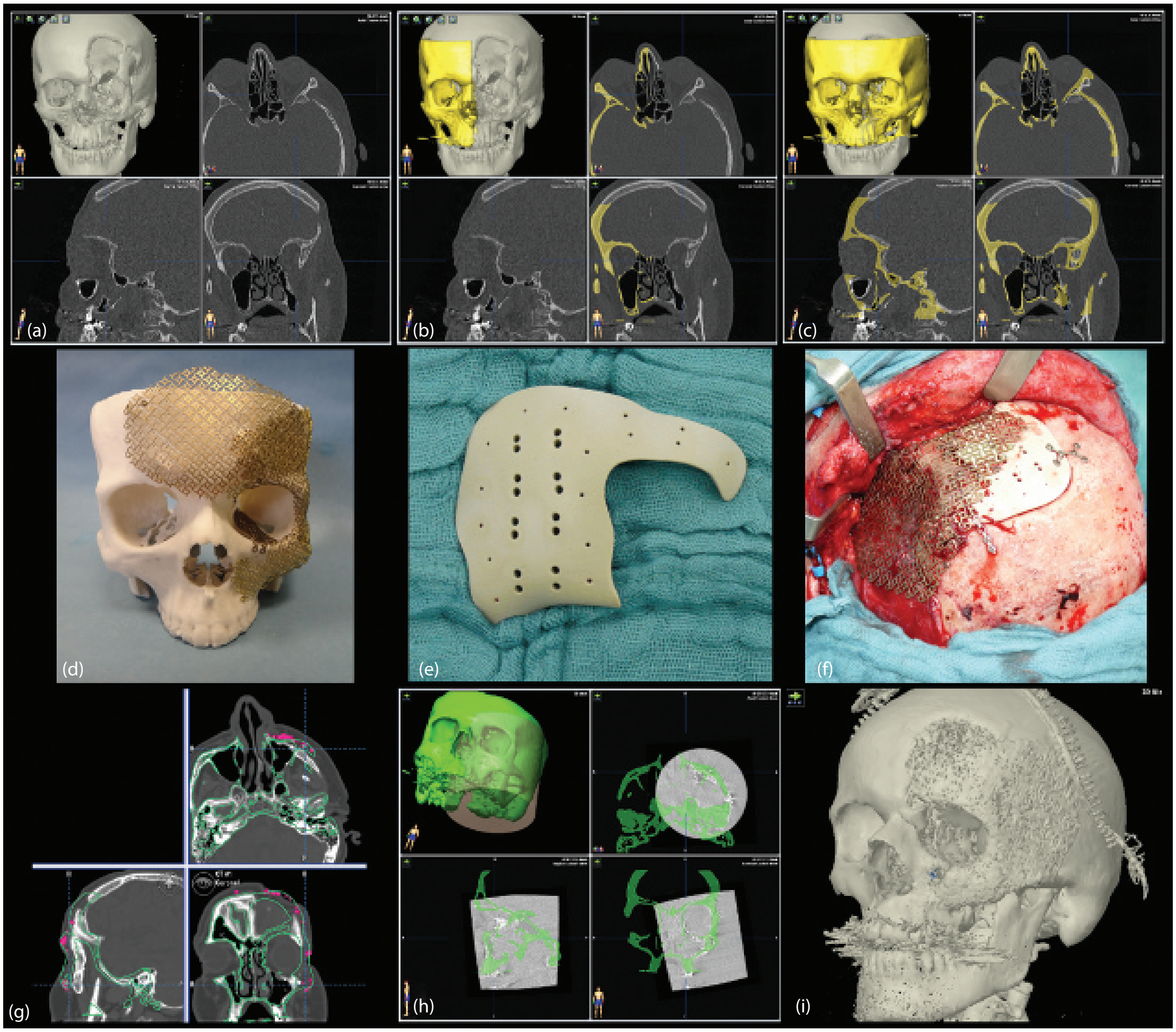


Figure 31.13 Computer-assisted secondary reconstruction of the midface. (a) Multiplanar representation of an inadequately managed comminuted fracture of the left midfacial region and post-operative craniotomy for brain abscess. (b) Multiplanar view of the virtual planning and creation of a template for midfacial reconstruction by automatic segmentation of the unaffected right side (yellow contour lines). (c) Multiplanar view of the virtual reconstruction by mirroring the unaffected side after bone segmentation using iPlan CMF 3.0 (BrainLAB®) (yellow contour lines). (d) Transfer of a virtual reconstruction into an STL data set that is used to create a 3D printed patient-specific plastic model. The 3D reconstruction model is used to form patient-specific implants from standard implants. (e) An additional patient-specific PEEK implant industrially manufactured for repairing a calvarial defect. (f) Intra-operative view after re-osteotomy of the left zygomatic bone and zygomatic arch complex and placement of patient-specific implants. (g) Multiplanar view of intra-operative navigation for an assessment of fracture reduction and the position of titanium implants. The pink contour line represents the surface of the inserted titanium implants. The green contour line shows the virtual template that was pre-operatively planned for the reconstruction procedure. (h) Multiplanar view of intra-operative 3D imaging with superimposition of virtual planning (green contour line). The reconstruction conforms well to the virtual template. (i) 3D view of a post-operative control CT.

- A more complex procedure involves the use of a standard implant that is manually bent in accordance with a patient-specific model and combined with manually manufactured positioning keys.

Both procedures can be used together with resection and cutting guides that enable surgeons to perform mandibular resection and harvest bone segments accurately according to planning. Resection and cutting guides can be manufactured either manually or by using CAD/CAM techniques in a manner analogous to virtual computer-assisted planning.

- An even more complex procedure of computer-assisted reconstruction involves the combination of a patient-specific CAD/CAM mandibular reconstruction plate and CAD/CAM resection and cutting guides.

Computer-assisted mandibular reconstruction surgery

Mandibular reconstruction using patient-specific preformed standard mandibular reconstruction plates

Pre-operative CT data sets allow patient-specific 3D models to be printed. These models can be used to pre-operatively bend a standard implant and thus to create a patient-specific implant. Whereas intra-operative navigation allows, for example, titanium mesh structures to be transferred to the midface, the orbits or the calvaria in a relatively accurate manner, fixation plates for mandibular reconstruction require the use of guides for plate positioning. This applies in particular to cases in which the standard technique for the fixation of mandibular reconstruction plates cannot be used anymore.

The procedure here referred to as the *standard technique* involves bending a reconstruction plate to the outer contour of the mandible before mandibular resection. The plate can be bent either intra-operatively or pre-operatively using a patient-specific mandibular model. Once the plate has been bent and positioned, it is fixated onto the mandible with a minimum of four screws, two of which are placed distal and the other two proximal to the mandibular segment to be removed. The position of the plate on the mandible is thus determined. The plate is removed and segmental resection is performed. Following resection, the plate is placed again on the mandible and fixated to the two remaining mandibular segments using the predefined screw holes. The use of locking plate systems allows the 3D structure of the mandible to be almost completely restored.

This standard method, however, has limitations and cannot be used if the outer cortex of the mandible is involved in the pathological process, if a secondary procedure is performed after segmental resection and the associated loss of mandibular continuity, and/or if a microvascular bone graft (e.g. fibula, iliac crest, scapula) is used for reconstruction. The standard method also cannot be used if the surgeon favours a plate shape that does not correspond to the outer contour of the mandible. This is the case, for example, if a plate is to be located more posterior in the mental region than the original outer contour in order to avoid an overly prominent chin or if a plate is to be located more medial in the lateral mandible than the original contour in order to allow a dental implant to be placed later at a prosthetically appropriate position (Figure 31.14a).

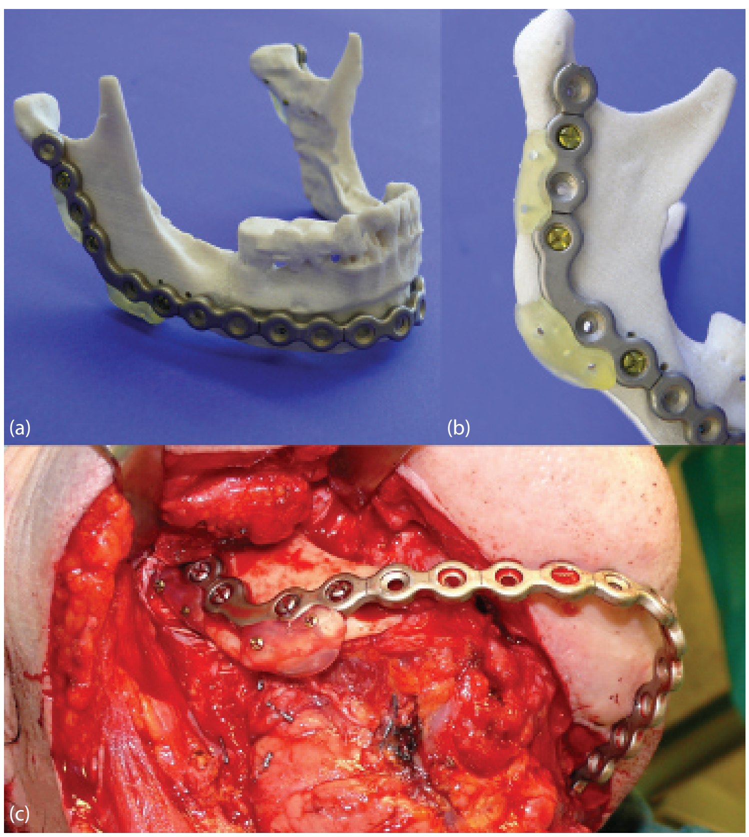


Figure 31.14 Patient-specific mandibular reconstruction plate with transfer keys and standard plates prebent on the basis of the patient models. (a) mandibular reconstruction plate prebent on the basis of a patient-specific model and fixed with screws. (b) Plastic transfer keys in the region of the right ascending ramus. (c) Intra-operative image showing the reconstruction plate fixed to the remaining mandibular segments by means of transfer keys. Transfer keys temporarily secured with mini-screws.

A wide variety of techniques, such as the use of an external fixator, the placement of K-wires and the fixation of the ramus, have been described and can be applied to avoid this problem.

Alternatively, positioning guides (transfer keys) can be made of plastic after the reconstruction plate is bent and fixed to a patient-specific mandibular model that has been manually milled into shape (Figures 31.14b,c and 31.15a,b). These positioning guides allow the position of the plate that has been planned by means of a model to be reproduced with a high degree of precision and thus allow a high accuracy of reconstruction to be achieved in terms of the position of the plate on the remaining mandible after segmental resection. This approach has the advantage that it does not require the previous (temporary) fixation of the reconstruction plate and the resection can be performed with no loss of accuracy. In addition, this allows freely shaped reconstruction plates to be created without compromising accuracy.

Mandibular reconstruction using preformed patient-specific CAD/CAM mandibular reconstruction plates

When CAD/CAM technologies are used to generate patient-specific implants and surgical guides, an STL data set is created on the basis of virtual surgical and reconstruction planning and exported into CAD software. Depending on what is needed where, patient-specific implants and the associated surgical guides are generated using CAM techniques. The implants are manufactured either by computerized numerical control (CNC) milling (Figure 31.16), SLM (Figure 31.17) or electron beam melting (EBM). By contrast, selective laser sintering (SLS) is the method that is usually used for creating surgical guides (Figure 31.18).

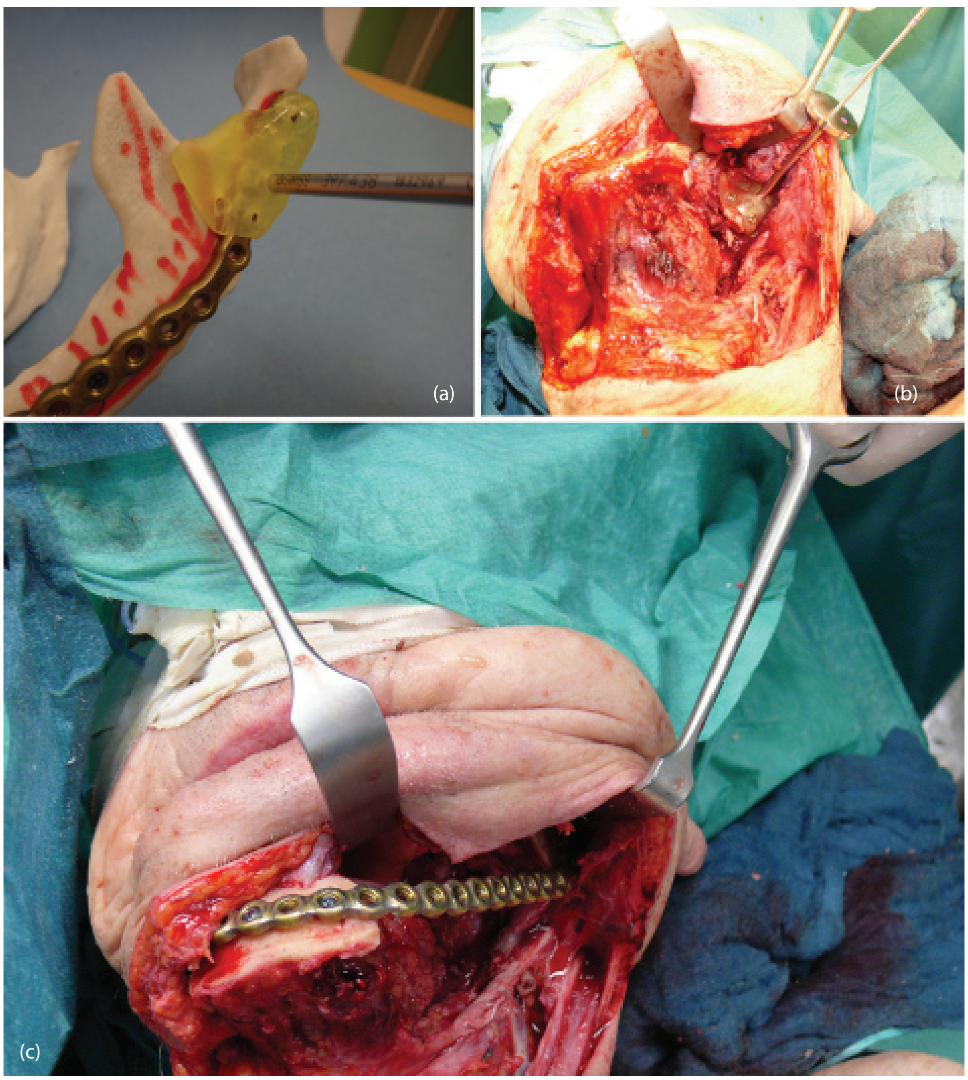
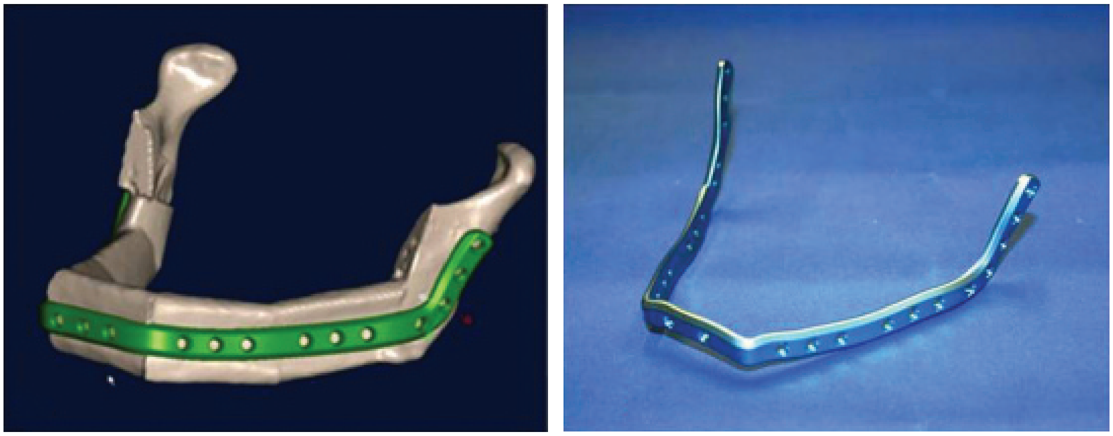


Figure 31.15 Patient-specific mandibular reconstruction plate with transfer keys in form of drilling guides and standard plates prebent on the basis of the patient models. (a) Plastic transfer keys in the region of the left ascending ramus in form of a drilling guide. (b) Intra-operative image showing transfer keys temporarily secured with mini-screws and the drill guide is inserted in the key to drill the hole in accordance to the model position. (c) Intra-operative image showing the reconstruction plate fixed to the remaining mandibular segments by means of pre-drilled screw holes.

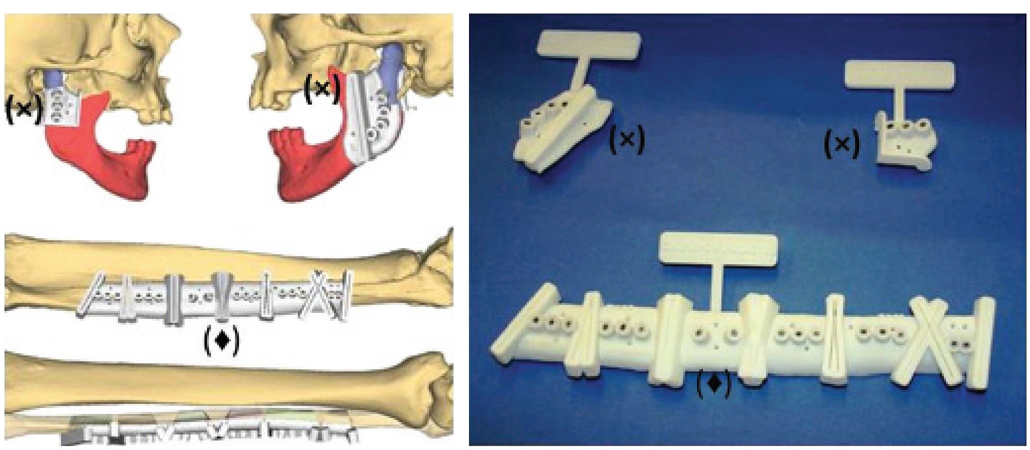


(a) (b)

Figure 31.16 (a) CNC-milled patient-specific mandibular reconstruction plate (DePuy Synthes®) for alloplastic mandibular reconstruction with a fibula flap. (b) CAD finished implant.

(a) (b)

Figure 31.17 (a) Patient-specific mandibular reconstruction plate made by SLM (KLS Martin®) for alloplastic mandibular reconstruction. (b) CAD finished implant.



(a) (b)

Figure 31.18 Surgical guides made from sterilizable polyamide by selective laser sintering (Materialise®). (×) Patient-specific resection guides with drill sleeves for pre-drilling the screw holes on the basis of the patient-specific mandibular reconstruction plate. (♦) Cutting guide for mandibular reconstruction with a fibula flap. The cutting guide also has drill sleeves identifying the screw holes for fixing the mandibular reconstruction plate. CAD finished guides.

These technologies allow workpieces to be manufactured with submillimetre precision.

One difficulty with these techniques is the accurate positioning of implants or guides at the surgical site. The presence of soft tissue, limited visibility or the absence of anatomical landmarks can complicate the positioning of implants or guides on the basis of planning and can lead to differences of a few millimetres between the planned reconstruction and the surgical result.

During pre-operative computer-assisted planning, a surgeon defines the margins of resection and determines the details of the planned reconstruction. In a next step, the desired size of a patient-specific mandibular reconstruction plate as well as the desired number, positions and angles of screw holes are individually planned according to anatomical and surgical requirements. Based on this planning process, a patient-specific mandibular reconstruction plate is designed using CAD software. Once the design has been approved by the surgeon, the plate is manufactured using CAM techniques.

The margins of resection and the position of the plate are transferred to the surgical site using guides, which too are planned with CAD/CAM technology and manufactured from polyamide using selective laser sintering. These guides are designed based on overall planning. Resection guides (Figures 31.18 and 31.19d,g) define the planned margins of bone resection. Information on the positions of screw holes defining the position of the planned plate after mandibular resection is encoded in drill sleeves in the resection guides on the basis of computer planning and thus transferred to the surgical site. To this end, sleeves are integrated into the guides, which allow holes to be pre-drilled for fixation screws (Figure 31.19g,h). This means that a segmental resection can be performed without prior fixation of the plate to the unresected mandible because the exact plate position has already been defined by the screw holes drilled by way of guides. In planned bone reconstructions involving vascularized or free bone tissue, cutting guides (Figure 31.19e,h) are also used. After fixation onto the harvested bone segment, they facilitate the segmentation of bone tissue in accordance with pre-operative computer planning. Here, too, screw hole positions are determined via drill sleeves in the gutting guides. Once bone segments have been harvested, they can thus be screwed to the plate in their planned positions (Figure 31.19h).

The introduction of CAD/CAM technology for the design and manufacture of patient-specific mandibular reconstruction plates, in particular in combination with surgical guides, has created a broad range of new opportunities for the planning and implementation of mandibular reconstructions. This applies not only to alloplastic reconstruction alone but also to reconstruction in combination with bone grafts or flaps. The insertion of a patient-specific mandibular reconstruction plate should also be considered in certain selected cases involving fractures. This approach offers the important advantage of individual flexibility with respect to patient-specific requirements. Compared with conventional techniques, it is also associated with shorter operative times because there is no need to bend the plate during the procedure and with considerably easier osteotomy and insertion of bone grafts or flaps.

VALIDATION AND QUALITY CONTROL

Whereas intra-operative imaging with a 3D C-arm makes post-operative imaging after midface reconstruction unnecessary in many cases, post-operative 3D imaging in addition to intra-operative imaging may still be required especially after panfacial and complex reconstructions of the facial skeleton and mandibular reconstructions.

In these cases, CBCT should theoretically be preferred to CT because it is associated with a lower effective radiation dose. Clinically, however, care must be taken to ensure that the field of view of the CBCT system is large enough to provide the necessary information. Since post-operative images of both bone and soft tissues may be required, a suitable imaging modality must be chosen after surgery. This applies, for example, to entrapped muscle tissue after orbital wall reconstruction and to the presence of intracerebral free air after a surgical procedure that involves the posterior wall of the frontal sinus or the region of the skull base. Despite a higher radiation dose, CT should therefore be preferred to CBCT in complex cases.

The purpose of intra-operative and post-operative 3D imaging is not only to perform a surgical procedure under radiological control but also to provide data sets for computer-assisted fusion with pre-operative image data sets and especially with pre-operative computer planning. Image fusion allows differences between pre-operative planning and surgical outcome to be visualized and, if required, to be quantitatively evaluated within the scope of quality assurance.

SUMMARY

As a result of advances in 3D imaging, 3D printing, intraoperative visualization and intra-operative navigation at the end of the last century and further improvements in these techniques in recent years, computer-assisted reconstruction of the facial skeleton has become an integral part of oral and maxillofacial surgery. In recent years, a workflow has been established which involves the following steps: *diagnosis planning and simulation surgical procedure validation and quality control*.

The focus of ***diagnosis*** is on 3D imaging especially on CT and on clinical findings.

Planning and simulation involves the creation of a virtual model of the desired surgical outcome. Apart from the fusion of different data sets, planning software allows the virtual models to be segmented in a user-friendly manner and to be manipulated (e.g. to be mirrored, shifted, rotated and modified) in an easy way. In addition, STL data sets can be imported and exported. When STL data sets are

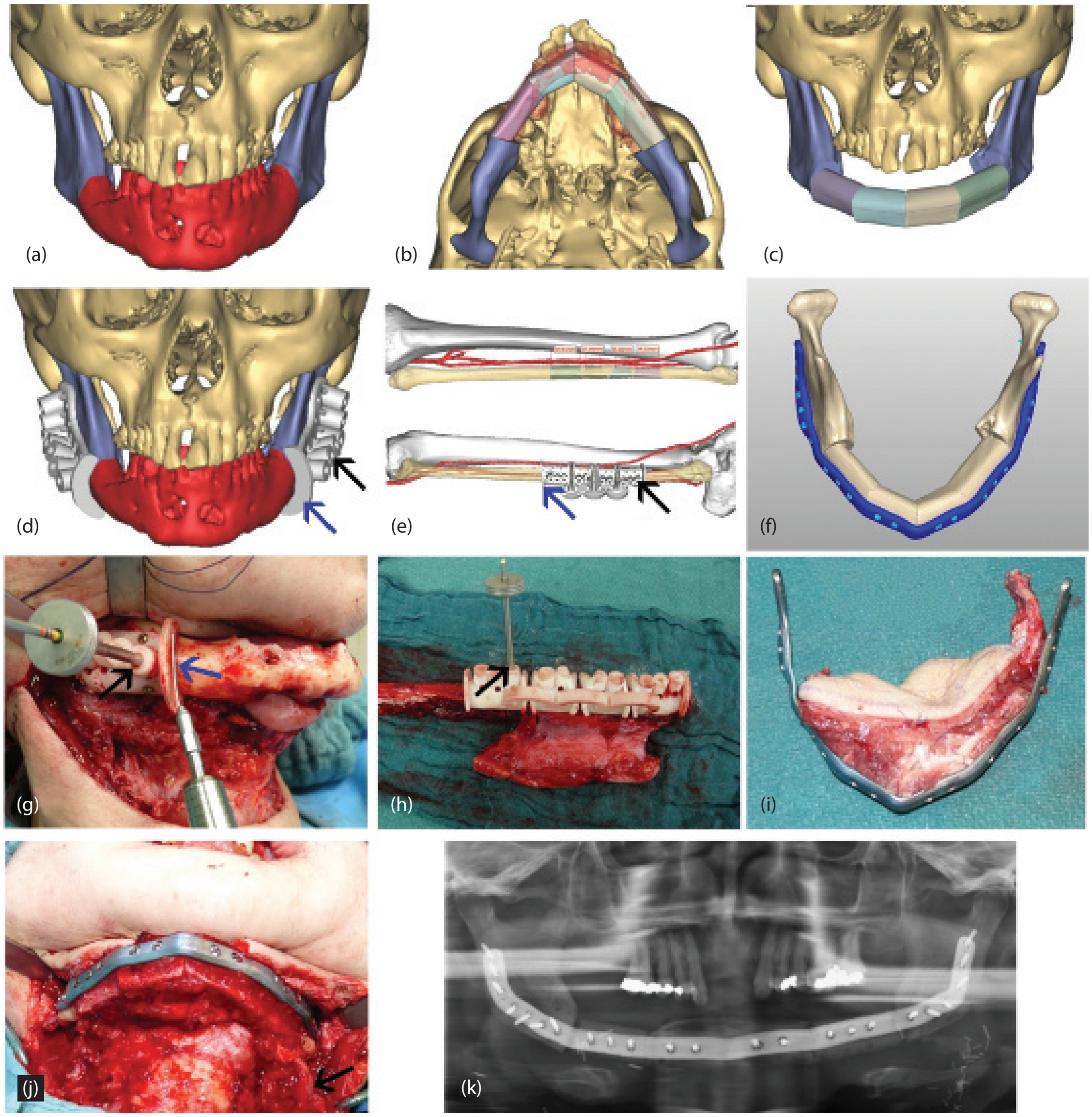


Figure 31.19 Mandibular reconstruction with a patient-specific reconstruction plate and a fibula flap with an intraoral skin island. (a) Virtual mandibular resection. View of the planned resection (red) and remaining bone segments (blue). (b and c) Virtual mandibular reconstruction with a four-segment fibula flap. Superimposition of the original mandible (red) and planned reconstruction (b). (d) CAD of resection guides for mandibular resection. Guides with drill sleeves that identify the planned screw hole positions. The black arrow indicates the drill sleeves and the blue arrow indicates that area of the guide that helps the surgeon guide a bone-cutting instrument (saw, osteotome, chisel etc.) (see also g). (e) Virtual fibula osteotomy lines and triangular bone segments that must be removed in order to obtain the shape of the neomandible consisting of four segments (top). CAD of cutting guides for harvesting fibula segments (bottom). Guides with drill sleeves that identify the planned screw hole positions (black arrow). The blue arrow indicates that area of the guide that helps the surgeon guide a bone-cutting instrument (see also h) (bottom). (f) CAD of the patient-specific mandibular reconstruction plate. Number of screws as well as the position and angle of each screw as predetermined. (g) Resection guide fixed with mini-screws for guiding a saw (blue arrow). Screw holes pre-drilled as planned (black arrow). (h) Bone-cutting guide fixed to the fibula with mini-screws. Integrated drill sleeves allow screw holes to be pre-drilled as planned (black arrow). (i) A fibula flap fixed to the patient-specific mandibular reconstruction plate using the pre-drilled screw holes. (j) Mandibular reconstruction with a fibula flap and a patient-specific mandibular reconstruction plate. Anastomosis of the pedicle of the fibula flap in the region of the left neck (black arrow). (k) Post-operative panoramic radiography of the reconstruction.

imported, the accuracy of implant fit can be virtually verified before surgery. When STL data sets are exported, patient-specific 3D models and virtual reconstructions can be directly printed and can be used for manufacturing patient-specific implants. STL data sets that are imported into CAD software are helpful in planning patient-specific implants and in manufacturing them using CAM techniques.

During the *surgical procedure*, planning must be transferred to the surgical site as accurately as possible.

A number of techniques are available for this purpose, e.g. closed reduction, open reduction with the placement of anatomically preformed or patient-specific implants in combination with surgical guides, and the additional use of navigation and intra-operative imaging.

After reconstructions of the midface, 3D imaging should be performed even before surgery is completed. Malpositions can thus be directly corrected and unnecessary open reconstructions or explorations – for example of the orbital walls – can be avoided. Mobile 3D C-arms are particularly useful for intra-operative 3D imaging.

Patient-specific surgical guides and patient-specific mandibular reconstruction plates are used in computer-assisted mandibular reconstructions. Surgical guides play the role of an interface between the virtual and the real world and are thus of crucial importance for an exact transfer of virtual reconstruction to the real surgical scenario.

Validation and quality control require post-procedural 3D imaging. Whereas intra-operative imaging with a 3D C-arm makes post-operative imaging after midface reconstruction unnecessary in many cases, post-operative 3D imaging in addition to intra-operative imaging may still be required after complex reconstructions of the facial skeleton and mandible.

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32

Transoral robotic surgery

JOSHUA E LUBEK

CONTENTS

INTRODUCTION

Transoral robotic surgery (TORS) is a modern technological advancement that involves the use of a remote console operated robot. Its application includes the removal of difficult access tumours within the oral cavity, oropharynx and supraglottis, thereby avoiding the use of extensive facial splitting approaches, pull-through surgical access approaches or radiation therapy. Benefits of TORS include complete surgical excision and pathologic tumour evaluation, decreased hospital length of stay, avoidance of radiotherapy (or de-escalated dosages) and associated long-term effects (i.e. osteoradionecrosis, dysphagia) with improved cosmesis via minimal access approaches.[1–4] Although its most common application is for the removal of squamous carcinoma of the oropharyngeal region, surgeons have continued to expand the scope of this robotic technology to other areas within the head and neck, including the management of sleep apnoea, thyroidectomy and neck dissection.[3,5,6] This chapter focuses on the use of TORS for the purposes of the management of tumours within the oral cavity and oropharynx.

INDICATIONS

Oropharynx

The incidence of oropharyngeal squamous carcinoma (OSCC) has undergone a significant increase throughout the world, with links to the human papilloma virus (HPV).[7] Surgery was historically reserved for salvage treatment often because of the need for extensive facial-splitting incisions, flap reconstruction and adjuvant radiotherapy due to initial advanced-stage disease presentation. As the management of OSCC shifts towards surgical management for early disease, the use of TORS will become advantageous. TORS long-term outcomes data are now available, demonstrating similar long-term disease free and overall survival as compared to radiotherapy, while minimizing risks of long-term radiation side effects such as osteoradionecrosis and dysphagia.[3,7–9] Weinstein et al. reported on a series of 47 patients who underwent TORS and neck dissection for OSCC.[1] Disease-free survival at 2 years was 90% with 38% of patients avoiding adjuvant chemotherapy and 11% of patients avoiding adjuvant chemoradiotherapy. The incidence of PEG tube dependence was 2.4% at 2 years which is similar to current chemoradiotherapy treatment rates. Another advantage suggested by TORS for OSCC includes the ability to accurately pathologically stage the tumour, resulting in more accurate patient-specific treatment (addition of chemotherapy or de-intensification of therapy). Walvekar et al. reported on a series in which clinical stage was altered in 40% of patients.[8] Larger resections requiring formal reconstruction can be managed with local flaps such as with the buccal fat pad, facial artery myomucosal (FAMM) or submental island flap. As surgeons have become more skilled in TORS, vascularized free flaps have also been inset using a robotic approach (Figure 32.1a through d).[3,9,10]

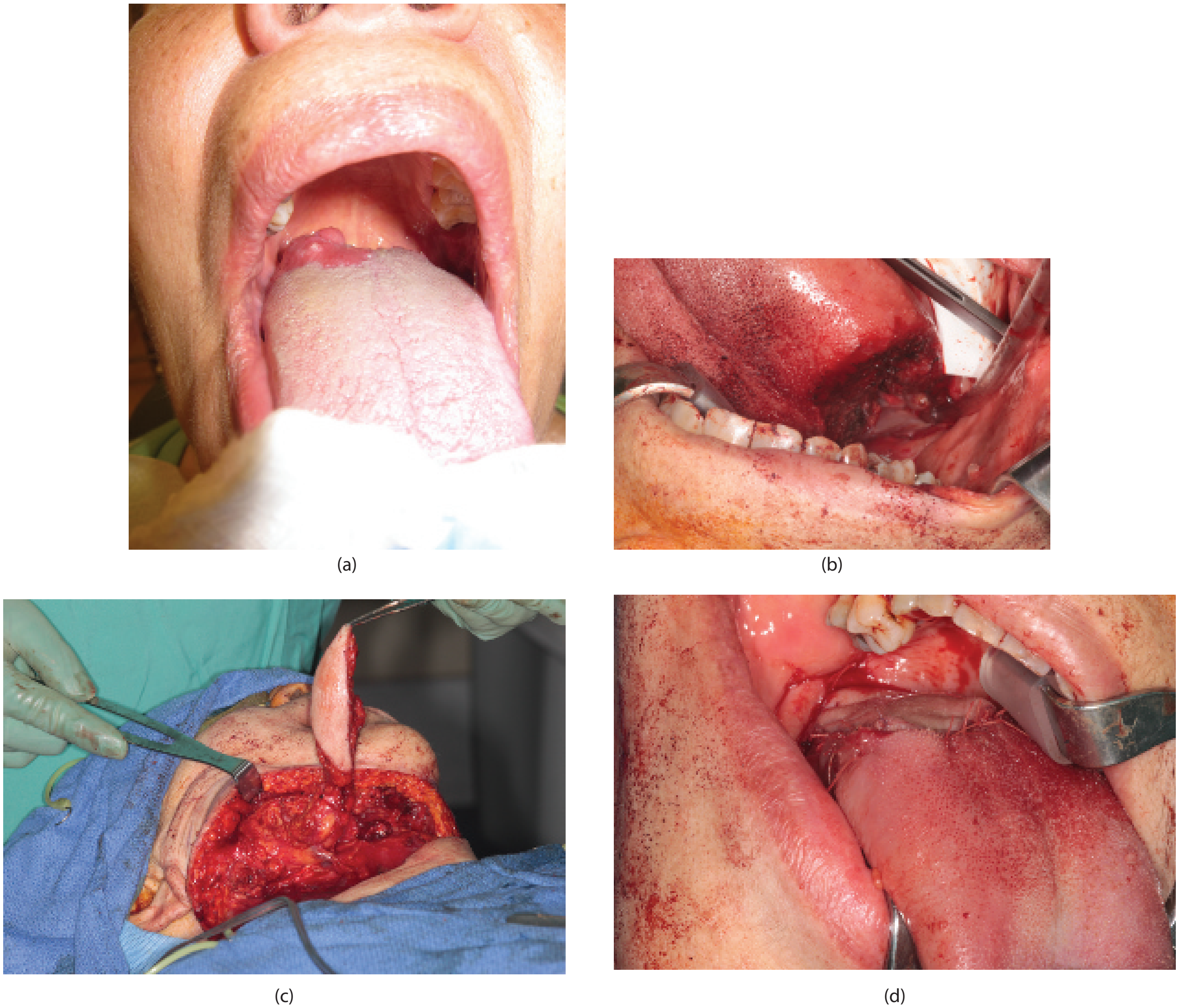


Figure 32.1 (a) Basaloid squamous carcinoma of the tongue base. (b) Tongue base resection defect using **transoral robotic surgery.** (c) Submental island artery flap elevated with selective neck dissection levels II, III and IV. (d) Flap inset.

Unknown primary

Approximately 4% of squamous cell carcinomas of the head and neck will present with metastatic cervical adenopathy without evidence of the primary source.[11,12] Traditionally, these patients would undergo panendoscopy, random biopsies and palatine tonsillectomy. If the primary source was not identified, then treatment would include broad field radiotherapy to the head and neck, resulting in significant morbidities such as dysphagia. Positron emission tomography in combination with computerized tomography (PET/CT) prior to panendoscopy has allowed the surgeon to focus biopsies on suspicious sites as detected on imaging with improved identification of the unknown primary. This is obviously important as it allows the radiotherapist to focus on the primary site thereby decreasing radiation toxicity. Between 15% and 60% of unknown primary head and neck carcinomas will occur at the base of tongue. Various series have described the use of TORS for base of tongue resection to help both locate and provide definitive surgical therapy simultaneously.[11,12] In a large multicentre trial for the unknown primary (n = 47), TORS was utilized to resect both the palatine tonsils and perform a simultaneous tongue base resection.[12] The primary tumour was identified in 70% of cases of which greater than 50% occurred at the tongue base. Neck dissection was also performed simultaneously once the primary was identified. The authors also reported that pre-operative exam and imaging failed to reveal the primary tumour in 38% of cases.[12]

Sleep apnoea

TORS technology is being adapted for the use in tongue base reduction surgery to aid in the management of

obstructive sleep apnoea.[3,5,6,13] It is often combined with other surgical therapies such as uvulopalatopharyngoplasty (UPPP) with minimal morbidity and improvements in patient apnoea-hypopnea indicies (AHI) in selected patients. Vincini et al. reported on a multi-centre trial of 243 cases with significant improvement in AHI, Epworth Sleepiness Scale and oxygen saturation.[13]

Lin and colleagues suggest that one major predictor of successful TORS tongue base reduction surgery is in the absence of lateral velopharyngeal collapse.[6] Glazer et al. reported on the safety of TORS surgery for severe OSA in 166 patients. In their series, only 6% of patients experienced major complications with one patient becoming feeding tube dependent due to significant dysphagia.[5]

SPECIALIZED EQUIPMENT

- Crowe–Davis retractor
- Feyh–Kastenbauer retractor
- Dingman retractor
- 5-mm endowrist Maryland dissector
- 5-mm endowrist scissor
- 5-mm endowrist Monopolar spatula tip
- 5-mm endowrist CO_2 laser attachment
- High-definition camera 0° and 30° lenses (8.5 or 12 mm diameter)
- Remote operating surgical robot and console. Currently, only the da Vinci Surgical System Model S or SI (Intuitive Surgical, Sunnyvale, CA) is available for TORS procedures (Figure 32.2a through d).

TECHNIQUE

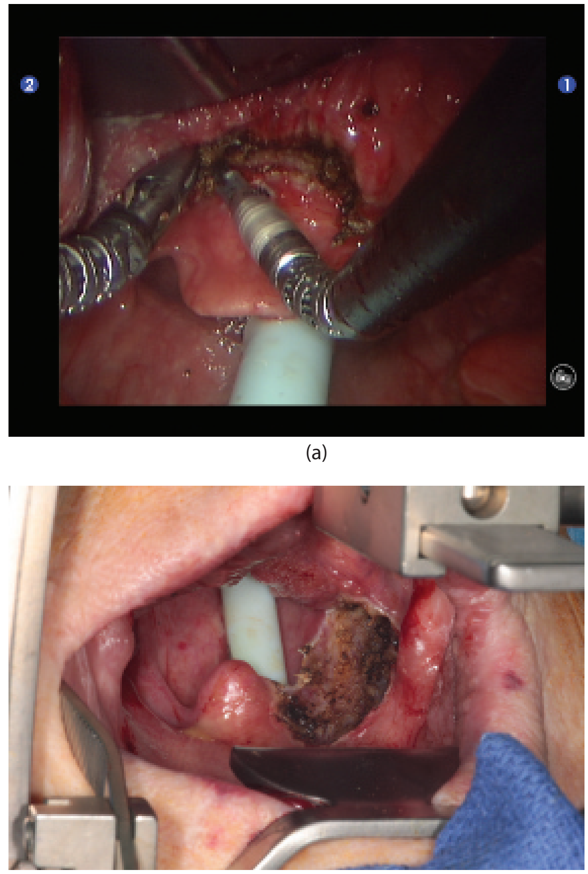
The patient is placed supine in the operatory and following induction of anaesthesia either a re-inforced naso-endotracheal tube (laser safe) is placed or tracheostomy performed. The patient is padded and the tube secured with the eyes protected with safety goggles. A shoulder roll also allows for ease of head positioning. Exam under anaesthesia is performed to re-evaluate the tumour prior to removal. Both direct visualization and manual palpation (if possible) are beneficial to aid in surgical planning.

(a) (b) (c) (d)

Figure 32.2 (a) Surgical 5-mm diameter operating instruments. (b) Surgical remote operating console. Two consoles are available to allow for teaching purposes or control of multiple instruments. (c) Feyh–Kastenbauer retractor suspended in position. (d) Robot in correct position and orientation to begin transoral robotic surgery procedure.

Figure 32.3 Surgical assistant can view the procedure on a high definition television monitor.

The mouth is opened with a mouth gag and the retractor of choice is placed to position the tongue. This will allow for visualization of the tumour at the tongue base, posterior pharyngeal wall, tonsillar fossa or other selected location within the oropharynx. Tooth guards should also be placed to protect the dentition and avoid ventral tongue injury from mandibular anterior tooth trauma. A suspension bar can be used to hold the retractor in position and help suspend the oropharyngeal/laryngeal structures. Next the robot (draped sterilely) is brought into position usually from either the left or right side of the patient starting at the foot of the operating table. The camera is positioned centrally with the operating arms in a 30°–45° position on either side of the camera and lowered into the oral cavity and oropharynx. The surgical assistant is scrubbed in and will help to suction, retract and change instruments on the various robotic arms (Figure 32.3). The surgeon is seated at the operating console and can now perform the surgical tumour extirpation. Tumour removal is most often performed with a monopolar bovie spatula tip. A Maryland dissector can be used to grasp tissue or provide tension to allow for ease of tissue cautery (Figure 32.4a and b). A specialized attachment can manipulate a CO_2 laser if so desired. The operating instruments are able to rotate 360° about their endowrist allowing for complete rotation within a confined space. Frozen section margins can be removed with a scissor attachment to avoid cautery tissue injury and difficulties in pathologic assessment. If a simultaneous neck dissection is to be performed, it can be performed either prior to robotic surgery or after completion of the tumour removal.



(a)

(b)

Figure 32.4 (a) Removal of a tumour involving the tongue base and vallecula. (b) Surgical site post-resection of a carcinoma of the tonsillar fossa.

Top tips

Initial start-up costs and operator experience

Robotic surgery (TORS) for the management of oral cavity/oropharyngeal disease is a costly endeavor (over 1 million US dollars per robot).[14] It requires the acquisition of specialized training skills for both the surgeon and auxillary support staff. At most institutions training involves practice in a simulation laboratory followed by proctoring by a surgeon already qualified in robotic surgery. One must also ask if the volume of cases will be sufficient to make this technology cost-effective both financially (important to the facility/hospital) and to provide maintenance of surgeon skills.

Patient positioning

The patient is positioned supine with the neck extended. Although actual surgical operative time is quite short (generally less than 30 minutes), robot set-up time can be quite lengthy especially with an inexperienced operative staff. One must ensure that the patient is adequately padded to avoid pressure sores and the eyes are protected to avoid corneal ulcers or pressure on the globes. The nasoendotracheal tube must also be secured to avoid any pressure on the nostrils which could result in alar necrosis (Figure 32.5). One should also apply caution in patients with cervical

Figure 32.5 Patient eyes protected and reinforced nasoendotracheal tube secured.

spine stenosis or arthritis, as neck extension is needed to improve visibility and placement of the robotic instruments.

Damage to adjacent structures

The da Vinci robot (Intuitive Surgical, Sunnyvale, CA) is remote console operated without haptic or tactile control. Although the high-definition camera makes it appear as if the operator is actually touching the tissue, there is no true feedback as to how much pressure is being applied. In standard surgical technique, this tactile feedback is very important in tumour extirpation and protection of adjacent healthy tissue.

A larger mouth opening allows for ease of access and improved visibility. Relative contraindications to the use TORS include significant trismus, severe retrognathia and a heavily restored dentition.[2,15] Teeth should be protected with tooth guards both in the maxilla and mandible. The lower tooth guard will also help to avoid inadvertent lacerations to the ventral tongue often caused by mandibular incisor injury during retractor pressure.

Airway management

Majority of oropharyngeal TORS procedures can be safely performed without the need for temporary tracheostomy. Consideration for tracheostomy should include pre-existing coagulopathies, significant bleeding, large tumour/need for flap reconstruction, cardiorespiratory insufficiency/poor performance status, high aspiration risk (neurologic, pre-existing dysphagia) and prior head and neck radiation. If the patient is not to have a tracheostomy serious consideration should be given to delayed extubation, approximately 24 hours post-procedure, to ensure adequate time for airway assessment and stability.

Significant tongue edema and airway obstruction can occur following prolonged application of the mouth/tongue retractors. To help minimize this, the tongue should be carefully positioned within the retractor. The retractor (i.e. Feyh–Kastenbauer) should be used for the minimum amount of time required for the robotic surgery. It can also be released periodically throughout the procedure (i.e. awaiting frozen section results). Moore et al. reported on a series of 66 patients who underwent TORS for OSCC. Initially, 17 patients received temporary tracheostomy of which 98.5% were tracheostomy-free at 2 years follow-up.[2]

Re-inforced endotracheal tubes and laser safety protocols should always be utilized as to avoid risk of airway fire or mucosal tissue injury.

Swallowing function

Temporary feeding tube can be considered for patients undergoing TORS procedures for oropharyngeal carcinoma. Most patients will have their feeding tube either removed during the peri-operative period. Routine swallow evaluation should be performed especially for removal of carcinoma of the tongue base. Temporary gastrostomy tube should be considered in patients who will require adjuvant radiotherapy, flap reconstruction or with pre-existing dysphagia/poor performance status. Sinclair et al. reported on a series of TORS-assisted resection for T1 and T2 OSCC.[15] Ten patients required post-operative gastrostomy tube placement with no patient using a tube beyond 1 year. One-third of patients had a continued perceived dysphagia with adjuvant chemoradiotherapy being a predictive factor for gastrostomy tube placement.

Surgical/clinical objectives

Ultimately, the purpose of TORS is to achieve negative pathologic margins with decreased patient morbidity in terms of both surgical complications and with hopes of de-intensification of adjuvant therapy or its avoidance entirely. The patient must understand that the TORS procedure may either be aborted, converted to an open conventional procedure or adjuvant therapy may be required.

Pre-operative imaging is important to evaluate for extent of disease within the oropharynx and neck. Magnetic resonance imaging (MRI) will help to provide soft tissue detail and depth of tumour at the primary site. Significant bleeding may be encountered involving the lingual artery with tongue base resection. This complication can be best avoided by identification and ligation of this vessel within the tongue base or during the neck dissection.

Neck dissection is most often performed simultaneously during the same procedure prior to the TORS component of the surgery (management of the primary tumour).[3,4] Advantages include the ability to manage the lingual artery or other significant branch of the external carotid artery, single anaesthetic procedure and complete pathologic evaluation. If a communication with the neck is encountered, formal reconstruction can be performed depending on the size of the communication. Arguments for a staged neck dissection (generally 1–3 weeks later) include avoidance of communication with the neck and primary tumour margin analysis. If the margin returns as positive on final evaluation it can be reresected at time of the neck dissection.

Further comparative studies are needed to fully understand the efficacy of TORS in the management of oropharyngeal carcinoma. As previously mentioned, current outcomes data do prove promising. One area of concern is in the management of the controversial retropharyngeal lymph nodes. This nodal basin medial to the carotid artery is reported to occur in approximately 10% of oropharyngeal carcinomas. They are most often involved in pharyngeal wall disease (20%) and lowest in base of tongue SCC (6% rate of incidence). Positive retropharyngeal nodes are associated with a poorer prognosis in certain studies.[16–18] These nodes are not dissected in the standard neck dissection for OSCC but are included in the standard radiation fields. Thus, as TORS procedures increase for management in OSCC disease; will there be an increase in failures within the neck (retropharyngeal region) especially if fewer patients receive adjuvant radiotherapy or receive de-intensification of radiotherapy?

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SECTION IV

MALIGNANT DISEASE OF THE MOUTH AND JAWS

33

Assessment and principles of management of head and neck cancer

PETER A BRENNAN and KISHORE SHEKAR

CONTENTS

INTRODUCTION

The overall incidence of oral and oropharyngeal cancer is on the increase. The patho physiology of the disease process has changed with an increasing incidence of human papilloma virus (HPV)–related SCC. There is also the emerging trend of increased incidence in younger patients. Treatment strategies have evolved to achieve better outcomes.[1] Surgery was the primary treatment of head and neck tumours. However, with emphasis on quality of life and advances in chemotherapy and radiotherapy delivery, there has been a shift in the management of oropharyngeal SCC. Despite many advances in the diagnosis and treatment, the crude overall 5-year survival of patients with head and neck mucosal cancer is still around 50%. Modern treatments have resulted in much better local control and improvements in quality of life. With the arrival of new chemotherapy agents and targeted monoclonal antibodies (such as the epidermal growth factor receptor antagonist, cetuximab), used in conjunction with standard modalities of treatment, overall survival will hopefully improve.[2]

The management of mucosal head and neck cancers is complicated by the involvement and/or close proximity of tumours to many anatomical structures, which are vital for normal function. Speech, swallowing, eating and speaking are all potentially affected by both the disease process itself and the resulting treatment. It is therefore essential that these patients are carefully assessed by a multidisciplinary team (MDT) before any treatment is advocated. In addition to surgeons, oncologists, radiologists, nurses, speech therapists, dieticians and pharmacists, it is often helpful to have a clinical psychologist and palliative care consultant available as well. We have found that taping the consultation is valuable as the patient is then able to listen with relatives outside of the hospital setting.[3]

Investigations prior to appointment in the head and neck clinic

The main routine investigations for a patient with suspected head and neck cancer are summarized in Table 33.1. Some specific investigations are discussed as follows:

- *General examination*. Examination of the patient for evidence of other disease (which might influence the choice of treatment) is important. Isolated suspicious neck lumps (in the absence of an obvious primary tumour) warrant examination of the other lymph node sites and abdomen. Suspicious lumps in the supraclavicular fossa should alert the clinician for possible primary pathology in the lung, gastrointestinal (particularly on the left side). In women, breast as a primary pathology should be considered and appropriate investigations arranged as necessary. Nutritional status should be assessed especially if major surgery is planned – the biochemical changes of the catabolic state following treatment lower serum albumin and may impair wound healing and recovery if the patient is already cachetic.
- *Examination under anaesthetic*. Some would consider that examination under anaesthetic (EUA) should be

Table 33.1 Summary of investigations

Basic investigations	
Nasendoscopy	
Examination under anaesthesia (may not be necessary for small and/or anterior tumours)	
Biopsy/fine needle aspiration cytology	
OPG	
Chest X-ray	
Full blood count	
Urea and electrolytes	
Liver function tests including clotting (INR)	
Staging CT or MRI of oro-pharynx and neck	
Chest imaging (see text)	
Special investigations (as required)	**Reason**
Doppler studies of radial and ulnar artery	Radial forearm free flap
Doppler studies of other areas	Perforator flaps
Arteriogram of lower limb, duplex scan	Fibula free flap
Fine needle aspiration cytology	Suspected neck metastasis
Ultrasound	Neck nodes of uncertain character on CT/MRI
PET/CT	Unknown primary, chest evaluation

Abbreviation: OPG, Orthopantomogram

a standard practice. This is in view of the incidence of synchronous tumours in the upper aero-digestive tract. With advances in imaging techniques (positron emission tomography-computed tomography and magnetic resonance imaging [PET-CT and MRI]) this may not be necessary. However, the authors recommended that in patients who require complex reconstruction especially in tumours involving the posterior structures of the oropharynx, and tongue base a EUA would help in planning future surgery. EUA would also confirm the resectability of tumours with a R0 margins, especially in those requiring paryngo-laryngectomies. It also enables the specialist anaesthetist to assess the patient at an early stage. It is worthwhile using pre-fabricated drawings of the oral cavity, oropharynx and laryngeal inlet to record the dimensions and extension of the tumour. Nasendoscopy can be used in the outpatient setting to examine inaccessible sites both before and after treatment.

- *Biopsy*. We would like to emphasize that an experienced senior staff member who is well versed in the identification of tumours should carry out a biopsy. This carries greater importance in patients with sub-mucosal disease and in those who require a bone biopsy. When performing a biopsy, either under local anaesthesia or during an EUA, it is important to take a sufficiently large piece of tumour, and ideally include some normal looking mucosa. Tumour depth is sometimes difficult to assess on a small incisional biopsy, but a generous biopsy may provide some idea of deep invasion (and therefore help plan definitive treatment the likelihood of neck metastasis) as well as providing information about possible dysplasia at the tumour margins. Tumours greater than 4 mm thickness have a much higher propensity to metastasize to the neck.[4] It is often worthwhile taking separate biopsies of apparently normal looking mucosa close to the tumour itself, as these may show dysplastic changes which might influence resection margins.

Blind biopsies are not helpful, especially when done at the time of EUA. It would be more useful to carry out targeted biopsies of sites with a potential to harbour tumour focci. These sites are dictated by findings on clinical examination and imaging. The authors prefer to call this as imaging dictated/clinically dictated targeted biopsy. This is a useful concept to bear in mind when dealing with occult primaries.

- *Fine needle aspiration cytology (FNAC)*. Useful adjunct in the assessment of enlarged neck nodes. Even small suspicious nodes of 5–6 mm can be biopsied using ultrasound-guided FNAC. Bear in mind that FNAC can lead to false-negative results (when tumour cells are not included in the aspirate), and therefore it is only one of the methods for assessing nodal status. A recent study found that a 23G (blue in the UK) needle is as diagnostically accurate and results in less patient discomfort than a 21G (green) needle and the authors recommends this smaller needle for head and neck FNAC.[5]
- *Orthopantomogram (OPG) and chest x-ray*. An OPG provides information about the state of the teeth as well as gross bone destruction (Figure 33.1). For oncologic purposes, it can be considered to be a screening investigation. It is helpful in osteotomy planning when an access procedure is required. It is always sensible to obtain a dental opinion before any treatment is commenced, and especially prior to radiotherapy, as early extraction of teeth with poor prognosis minimizes the later risk of osteoradionecrosis. Extractions can usually be performed at the time of EUA. A routine chest x-ray adds very little value.

Figure 33.1 Orthopantomogram showing bone destruction in the lower left quadrant.

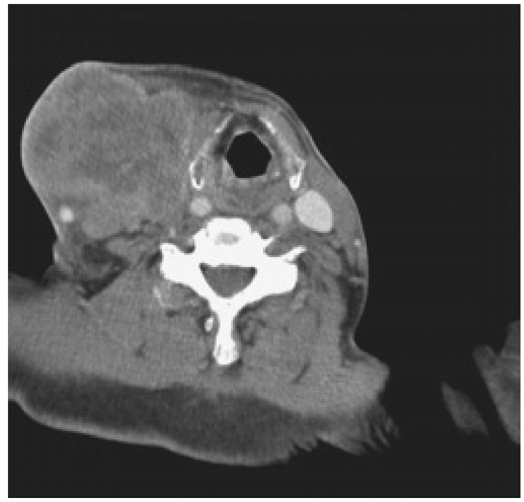

Figure 33.2 Computed tomography scan showing necrosis within lymph nodes indicative of squamous cell carcinoma.

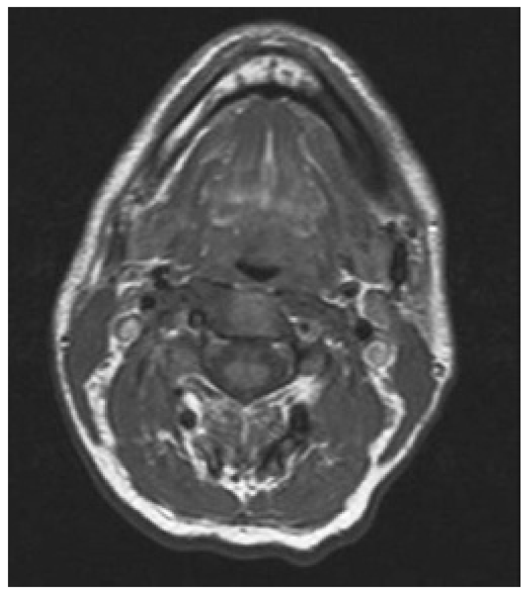

Figure 33.3 T1-weighted MRI from the same patient as Figure 33.1 showing extensive loss of bone marrow signal indicating tumour spread.

- *Routine blood investigations*. Full blood count, urea and electrolytes and liver function tests are routine baseline tests that should be performed in any newly diagnosed head and neck patient. With the increased use of chemotherapy, renal function needs to be known before adjuvant treatment. Head and neck patients may have liver disease as a result of chronic alcohol ingestion. If major surgery is planned, chronic alcoholic patients should ideally be detoxified for a week or so prior to their operation to minimize the complications of acute alcohol withdrawal. One should remember that liver disease may result in changed clotting factors, and indeed an INR is one of the most sensitive tests of liver function. It is also useful to know the pre-operative albumin levels. Where there might be a wait for a surgical date, it may be useful to consider feeding patients with high-protein diet via a nasogastric or gastrostomy tube. There is evidence to suggest that feeding patients a high-carbohydrate diet 24 hours prior to surgery improves post-operative healing and recovery.
- *Cross-sectional imaging*. Both CT and MRI have advantages and disadvantages. Both can be used to image the neck for possible lymph node metastasis, but neither is sufficiently sensitive to detect micro-metastases. However, both CT and MRI will show necrosis within lymph nodes,[6] a finding which is usually indicative of squamous cell carcinoma, rather than lymphoma (Figure 33.2). MRI cannot be used to assess the lungs and some claustrophobic patients find the examination intolerable. In future, open magnet machines may make the examination easier for these patients. Whilst cortical bone is poorly imaged on MRI (due to the lack of water molecules), bone marrow provides high signal, and loss of this signal can be a sign of bone invasion (Figure 33.3). MRI is also useful in complex anatomical areas such as the infra-temporal fossa and tongue base. MRI may overestimate the size of tumours due to associated inflammation, but with all imaging, tumour size can be underestimated. An example is the superficially invasive tongue cancer which might not even be evident on a cross-sectional scan.
- CT is a much quicker procedure, but a considerable amount of ionizing radiation is used (8 mSV – equivalent to 400 chest x-rays) and there is a greater risk of an adverse reaction to the intravenous contrast. There is still controversy about whether to CT the chest in patients with head and neck cancer. The incidence of lung metastasis in patients with small T-stage tumours is low and higher in patients with multiple or large neck metastasis, particularly if in the low neck levels (III–V). The authors recommend staging of chest in all patients at stage II and above. CT chest for stage I disease will depend on the local MDT protocols.

- *Ultrasound (US)*. Ideal for assessing lymph nodes both prior to, and following treatment. Its ability to assess the size, shape, consistency (presence or absence of normal node hilum) and vascularity (with colour flow Doppler) of a node is invaluable. US is more sensitive than CT in assessing small metastatic nodes (less than 6 mm), particularly when used with FNAC.[7] It is also helpful in guiding fine needle biopsies in deep or impalpable nodes. The use of US in following up patients after treatment is to be encouraged. With appropriate training, surgeons can perform US in the clinic, and they have the advantage of knowing the underlying anatomy in great detail. Liver US may be indicated with deranged liver function tests, or when a liver is palpated during routine examination. Some advocate the use of intraoperative US with small, high-resolution probes to guide primary tumour resection although this technique is not in widespread use. The use of US and guided FNAC has led to the development of one stop clinics. This has reduced the patient's journey, resulted in early diagnosis and proved to be cost effective.
- *PET-CT*. The localization of the positron-emitting agent 18 fluoro-deoxyglucose (FDG) with CT has enabled even small tumours to be localized. PET-CT may have a role to play in the assessment of the unknown primary tumour and to evaluate suspicious chest nodules.[8] However, FDG is also taken up following biopsy (even several weeks later) and therefore may give rise to false-positive results. In patients with a high index of suspicion of an unknown primary/occult disease it is paramount that a PET-CT is done before EUA and targeted biopsy. In time, there may be specific monoclonal antibodies developed that will bind to cancer cells enabling their detection (for example to specific cellular adhesion proteins). Studies are looking to see if the quantitative uptake of 18 FDG will improve the predictive value of PET- CT.

PRINCIPLES OF MANAGEMENT

As mentioned previously, all patients need to be seen in a multidisciplinary combined head and neck clinic so as to ensure that an optimum treatment recommendation is made. Historically, patients would have been treated initially either by surgery or radiotherapy, or with a combination of both. More recently, the use of neoadjuvant chemotherapy prior to definitive treatment is gaining popularity, particularly with large volume disease, and tumours involving structures such as the soft palate. The concept of ‘organ-preserving treatment’ should be considered. Although resection and reconstruction of, for example, the soft palate may produce a good surgical result, it will never function in the same way as before treatment. Neoadjuvant chemotherapy often shrinks the primary tumour considerably but whether resection of the primary tumour should be to the same margins as before chemotherapy is controversial, since there is no randomized clinical trial comparing this in head and neck cancer.

Treatment will either have curative or palliative intent and it is important to establish this at an early stage whether there is a realistic chance of cure.

Factors influencing the choice of treatment—All of the following factors need to be considered when planning treatment:

- General parameters such as age, medical co-morbidity (such as ischaemic heart disease, peripheral vascular disease, obstructive airway disease, nutritional status, liver and renal compromise), as well as social implications, including smoking and alcohol consumption all need to be considered. For example, an elderly patient with a life-long smoking history who drinks 70 units of alcohol per week may require ‘medical optimization’ and a high calorie and protein diet (possibly by nasogastic or gastrostomy feeding) to reduce the likelihood of significant post-operative complications if major surgery is planned. For posterior oropharyngeal tumours, it is sensible to place a percutaneous endoscopic gastrotomy (PEG) at an early stage to enable feeding post-operatively. This is also important when radiotherapy fields may result in a severe pharyngitis, and dysphagia making eating difficult or impossible.
- *Tumour site*. Both surgery and radiotherapy can be used for treatment of lip cancers, although radiotherapy is arguably better in advanced disease. Primary surgery or radiotherapy can be used for definitive curative treatment of intraoral tumours, but only surgery is likely to be curative when bone is involved. Small tumours respond equally well to radiotherapy at all sites. The results are comparable to surgery. However, for advanced tumours at all sites in the oral cavity, primary surgery followed by adjuvant chemoradiotherapy is recommended for better disease control and survival. Oropharyngeal tumours, especially HPV + tumours respond better to chemoradiotherapy with better quality of life for patients. Surgery at these sites is often for recurrent disease or for a new primary where radiotherapy as an option has been exhausted by previous treatment. Neoadjuvant chemotherapy (given before surgery or radiotherapy) may also be indicated, particularly with large tumours and/or those involving such sites as the tongue base or soft palate). Concurrent chemotherapy (given at the same time as radiotherapy) is also used in some centres. Radiotherapy can be used for palliation, but may result in osteoradionecrosis and its associated complications.
- *Tumour size*. Surgery is ideal for small T1 and early T2 tumours as long as function is not severely compromised. With larger tumours, each case will be discussed at an MDT and an appropriate treatment decision will be made. In many cases, ablative surgery with microvascular reconstruction is followed by radiotherapy if this is indicated following pathological analysis of the resection specimen. Neoadjuvant chemotherapy (using a combination of drugs such as 5-fluorouracil, cisplatin and docetaxel) is particularly useful in large tongue base and soft palate/pharyngeal wall tumours

prior to surgery or radiotherapy. To date, there has been no clinical trial comparing neoadjuvant chemotherapy versus surgery or radiotherapy alone on patient survival.

- *Histology.* The likelihood for neck metastasis is increased with poorly differentiated primary tumours. However, many surgeons would consider a tumour depth of 4 mm or more to be a greater predictor of neck metastasis. Perineural and vascular invasion are also bad prognostic indicators, as is an infiltrating tumour front (as compared to a cohesive pattern). Field change at the tumour margin – which may be present clinically, or be apparent from dysplastic changes in biopsies – is a worrying feature. Radiotherapy can change these dysplastic areas into invasive carcinoma, so it is not surprising that surgery is usually used in these cases.
- *Neck status.* Should be considered with the primary tumour when deciding treatment. Even with small T1 tongue cancers, with a depth greater than 4 mm, the risk of nodal micro-metastasis can be above 20%. In this situation, most clinicians would advocate an ipsilateral selective I-IV neck dissection both to stage the disease pathologically and to remove possible micro-metastatic disease that may not be evident on the pre-operative imaging. The management of the node positive neck is less controversial and may be treated either by surgery or chemoradiotherapy, depending on the MDT decision. A modified radical neck dissection (ideally with preservation of the accessory nerve) is the usual surgical treatment, but recently the value of dissecting level V has been questioned in certain circumstances, and some would advocate a more limited procedure. The reader is referred to an excellent recent review on selective neck dissections.[9]

The overall survival and disease-specific survival is reduced by 50% in patients with N + neck for all T stages.

- *Previous radiotherapy.* It is not usually possible to reirradiate the same target volume twice, and recurrent disease in these situations is best treated surgically. For recurrent neck disease, it is sometimes useful to bring new vascularized tissue (including skin) into the area which will enable further radiotherapy to be given if needed. The use of intensity-modulated radiotherapy (IMRT) enables radiotherapy to be delivered to a tumour volume with greater precision than conventional techniques, thereby reducing its side effects (for example parotid gland sparing).[10]

BASIC PRINCIPLES OF CURATIVE SURGERY

- *Primary tumour.* The surgeon should have a three dimensional impression of the tumour in their mind. The resection should be marked to include a clinical margin of at least 10 mm. The author routinely uses a Colorado mono-polar diathermy needle both to mark the resection. The resection per se can be performed with either a Colorado needle (using coagulation setting) or a harmonic scalpel. In the recent past, the use of Lugol's Iodine as an adjunct has helped to better delineate resection margins. This technique helps in controlled excision of dysplastic areas surrounding the invasive component. This has the drawback of increasing the total volume of resection. Meticulous haemostasis is paramount – for example, the lingual artery can be tied off posteriorly early on during a lateral tongue resection or the maxillary artery tied off prior to the completion of cuts for a maxillectomy via a anterolateral corridor access. Access osteotomies are useful for posterior tongue, some soft palate and pharyngeal/parapharyngeal tumours as well as for those in the infra-temporal fossa.

There is controversy about the use of frozen sections at the time of resection. The authors do not use routinely frozen section for margin control. A more appropriate technique is to pre-operatively carry out volume rendering on the scans and determine the resection margins based on sound anatomy. Inevitably, there will be some shrinkage both after resection and placing the specimen in formalin and the definitive pathological margin may be less than that obtained clinically. Close and involved margins are associated with poor prognosis.[11]

- *Neck dissection.* Once again, meticulous technique is essential. Depending on the disease process. Vital anatomical structures should be preserved (particularly the accessory and marginal mandibular nerves). It is debateable whether the primary resection needs to be included en bloc with the neck dissection for floor of mouth and tongue tumours. We prefer to carry out an incontinuity resection of the primary with the neck in cases where a false-positive margins (deep) may be reported on final histology (floor of mouth tumours invading the mylohyoid, retromolar trigone tumours involving the palatoglossal attachment). In tumours close to the midline, a bilateral neck dissection should be considered.
- *Reconstruction.* The details of the different reconstructive techniques are provided elsewhere in this book. The reconstructive options depend on size of the defect, patient co-morbidity and operator preference. Small defects can be closed primarily or by using a small local flap such as the buccal fat pad. Alternatively, they can sometimes be left to granulate. For larger defects, microvascular free tissue transfer has revolutionized reconstructive options. It is always sensible to have a 'plan B' so that in the event of problems with the first choice of reconstruction another option is available (whether that is a different microvascular flap or pedicled flap). In these long cases, it is important to ensure that the surgeon protects his own health – take regular breaks, and consider using an operating chair or risk back problems in later life! The use of more than one free flap for reconstruction is not that uncommon. One size does not fit all. It is important that the reconstructive surgeon should be well versed with the various armamentariums of flaps available. The authors work in a team to achieve this end.

- *Temporary tracheostomy*. This should be discussed at the MDT, and is dependent on tumour size, site and co-morbidity. Patients can often be de-cannulated at an early stage.

PALLIATIVE SURGERY

Surgery has a role in the palliative patient. Debulking of tumours including fungating neck metastases often improves quality of life even if only briefly. It is wise to consult the palliative care team at an early stage for their input. Potentially mutilating surgery when there is no chance of cure is to be deprecated, especially if this leaves the patient in a worse state. In this respect, functional outcome needs to be considered before embarking on major palliative surgery. Palliative neck surgery is sometimes useful (Figures 33.4 and 33.5), but skin incisions need to be planned carefully to minimize great vessel compromise and possible blow out at a later stage. Occasionally, 'palliative surgery' gives unexpectedly good long-term results (Figure 33.6).

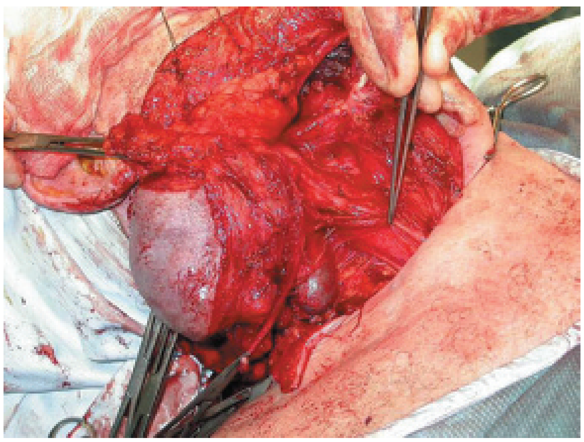

Figure 33.4 Modified radical neck dissection type I (with preservation of the accessory nerve) – same patient as Figure 33.2.

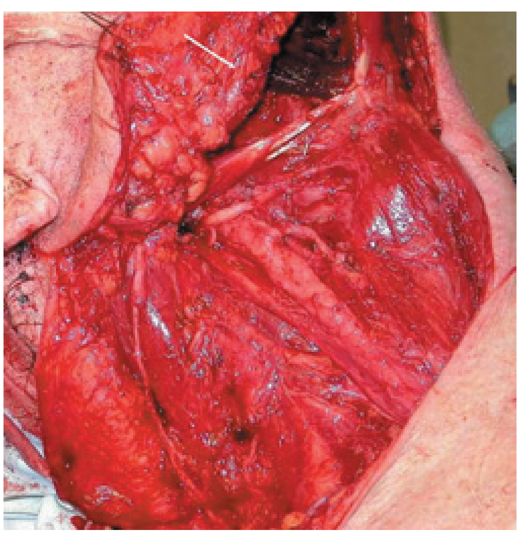

Figure 33.5 Good nerve function immediately post-surgery.

Figure 33.6 Patient still alive with no evidence of disease 2 years post 'palliative surgery'.

Top tips

- Think of the whole patient – consider medical history and co-morbidity when making treatment decisions.
- For large and/or posterior tumours, consider placing a PEG at an early stage.
- Concept of organ preservation, and function after treatment.
- Open treatment discussions taking into account the views of the patient and all members of the MDT team.
- Advanced disease at initial presentation might be best managed palliatively – just because you can operate, doesn't mean you should!
- Think about your own health – take regular breaks and consider using an operating chair and work in teams.

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34

Percutaneous Endoscopic Gastrostomy

PEYMAN ALAM

CONTENTS

Percutaneous endoscopic gastrostomy (PEG) is an endoscopically assisted procedure, where a tube passed through stomach to the abdominal wall (Figure 34.1) to facilitate patient's enteral feeding.

The procedure was first performed in 1979 and in 1980, the technique was published by Gauderer et al.[1] In 2001, Gauderer published the details of the development of the procedure.[2]

INDICATIONS

The two main indications for placement of percutaneous gastrostomy tube are access for enteral feeding and decompression of the gut.

Gastrostomy may be indicated in situations where normal or other forms of enteral feeding (e.g. nasogastric) is not possible. Some of these situations may have anatomical causes (during the process of cleft lip and palate correction), neurological causes (stroke, cerebral palsy, brain injury and impaired swallowing) or other causes such as recent surgery of the upper gastrointestinal (GI) or the respiratory tract, head and neck tumours, surgery or radiotherapy.

A gastrostomy can also be used to decompress the stomach contents in a patient with a malignant bowel obstruction. This is referred to as a 'venting PEG' and is placed to prevent and manage nausea and vomiting.

Contraindications

Inability to pass the endoscope through the oesophagus, limited life expectancy, uncontrolled coagulopathy and peritonitis are examples of absolute contraindications to PEG tube placement.[3,4]

However, there are relative contraindications which include portal hypertension, prior subtotal gastrectomy, peritoneal dialysis, hepatomegaly, large hiatal hernia, infiltrative or malignant disorders of the stomach, morbid obesity and anorexia nervosa.[4–6] A critical literature review by Goldberg and Altman evaluated role of gastrostomy tube placement in advanced dementia with dysphagia. They found no evidence to suggest long-term survival rates improvement.[7]

Table 34.1 summarizes the contraindications of PEG.

Technique

Since development of the procedure, various guidance methods such as endoscopic, fluoroscopic and ultrasound techniques have been described; however, the main distinction between different techniques is based on the way the tube enters the stomach, namely, transoral (Ponsky technique)[8] or transabdominal (Russell technique).[9] There are different tube designs and as a result associated advantages/disadvantages with each technique. For example, reports suggest higher peritubal infection rate and gastrostomy tract seeding with tumour in patients with upper GI tract or ear/nose/throat cancers in transoral approach.[10]

On the other hand, transabdominal tubes are smaller in diameter and less secure resulting in more frequent occlusion and dislodgment.[11]

A meta-analysis by Wollman et al. found a higher success rate (99.2% vs. 95.7%) and lower complication rate (13.3% vs. 29%) for transabdominal versus transoral gastrostomy[12] but more recent studies have reported similar outcomes for both techniques.[13–15]

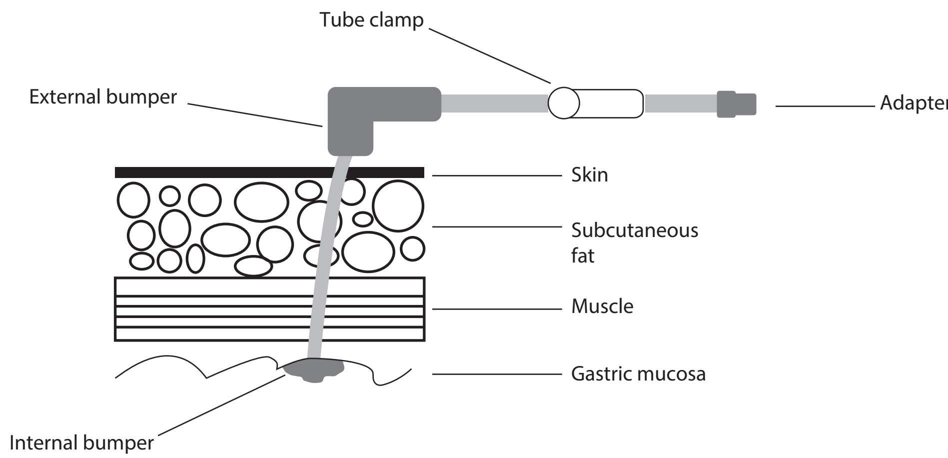

Figure 34.1 Schematic diagram of bumper type percutaneous endoscopic gastrostomy (PEG) tube.

Table 34.1 Absolute and relative contraindications of percutaneous endoscopic gastrostomy (PEG).

Absolute contraindications
Lack of informed consent
Inability to perform an oesophagogastroduodenoscopy
Uncorrected coagulopathy or thrombocytopenia
Severe ascites
Sepsis
Bowel ischaemia
Intra-abdominal perforation
Active peritonitis
Abdominal wall infection at the selected site of placement
Gastric outlet obstruction and severe gastroparesis (unless PEG is used for decompression)
History of total gastrectomy
Relative contraindications
Presence of oropharyngeal or oesophageal malignancy (potential risk of seeding of the PEG tract)
Hepatomegaly
Splenomegaly
Portal hypertension with gastric varices
History of prior abdominal surgeries (possible presence of adhesions and bowel interposition)
Ventral hernia
Peritoneal dialysis
History of partial gastrectomy
Massive *ascites*
Gastric mucosal abnormalities: large *gastric varices*, portal hypertensive gastropathy
Previous abdominal surgery including previous partial gasterectomy: increased risk of organs interposed between gastric wall and abdominal wall
Morbid obesity: difficulties in locating stomach position by digital indentation of stomach and transillumination
Gastric wall *neoplasm*
Abdominal wall infection: increased risk of infection of PEG site
Intra-abdominal malignancy with peritoneal involvement (tumour seeding into formed channel with subsequent failure)

- Obtain appropriate consent.
- Preparation of the abdomen, intravenous antibiotic administration and adequate sedation and analgesia.
- An oesophagogastroduodenoscopy (OGD) is performed in order to evaluate the anatomy of the stomach.
- Stomach insufflated.
- Using the endoscope light, the abdominal wall is trans-illuminated (Figure 34.2).
- Finger pressure is applied at the point of maximal transillumination with resultant indentation of gastric lumen wall which can be observed endoscopically. Transillumination and finger pressure manoeuvres help to ensure that there is no organ between the anterior stomach wall and the skin.
- This area which should be at least 1 in. below the costal margin and away from the xiphoid process is marked on the skin.
- After adequate local anaesthetic infiltration of the marked area, 1 cm horizontal skin incision is made and the needle catheter passed from the abdominal wall into the stomach which should be visible endoscopically.
- Snare is passed through the endoscope into the stomach.
- Needle is removed and the guidewire is passed through the catheter into the stomach (Figure 34.3) and grasped with snare and pulled out of the mouth along with the endoscope.
- The catheter is then removed back over the guidewire.
- The pointed end of the PEG tube is then secured to the looped end of the guidewire, lubricated and the skin end of guidewire is pulled allowing the PEG tube to pass through the mouth, oesophagus and stomach out through the skin.
- Avoiding excessive tension, pull the PEG tube till internal bumper lies against the gastric lumen wall.
- To secure the PEG tube, use the external bumper (Figure 34.4).

Figure 34.2 Showing transilluminated light through abdominal wall.

Sacks–Vine technique (push method) is similar to the pull method described earlier except that the PEG tube is pushed over the single guidewire.[16]

Russell introducer technique, describes gastrostomy by passing wire directly into the stomach under endoscopic visualization.

Series of dilators are passed over the wire by using Seldinger technique to increase the size of the gastrostomy thus allowing final tube to be pushed over the wire into the stomach.[17]

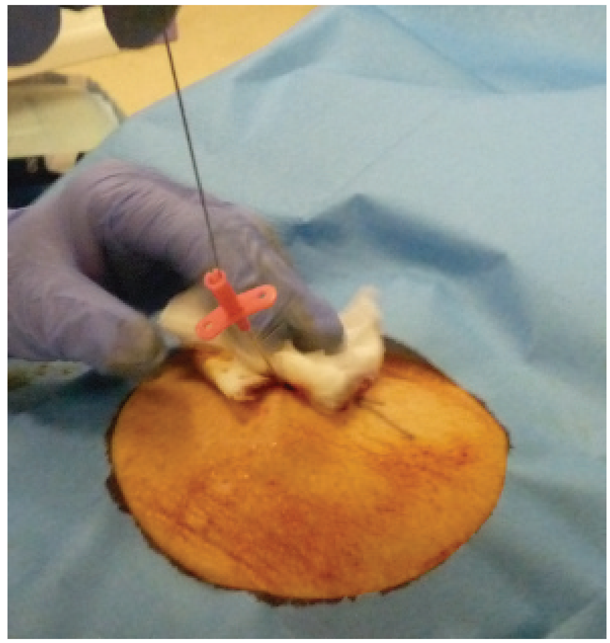

Figure 34.3 Showing the guidewire is passing through the catheter into the stomach.

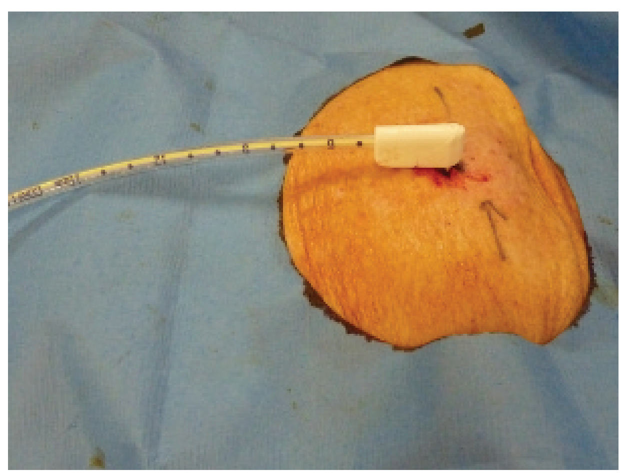

Figure 34.4 PEG tube secured with external bumper away from the skin.

This technique is less likely to cause oropharyngeal mechanical damage resulted from passage of feeding tube and can potentially reduce the risk of oropharyngeal bacterial contamination and metastatic seeding from tumours.

Initiation of feeding

Older literature suggested initiation of feeding between 12 and 24 hours after placement of transoral tubes; however, more recent prospective randomized studies demonstrated initiation of feeding as early as 3 hours post placement.[18–20]

And even, Stain et al. in their randomized control trial concluded that in acutely ill intensive and intermediate care patients, immediate enteral feeding via a PEG tube is as safe as next-day feeding.[21]

These data were further analysed and confirmed by Bechtold et al.[22]

Gastrostomy tube change

Eventually all tubes will require replacement due to occlusion, breakage or dislodgement; however, with good care, most transoral bumper-type gastrostomy tubes can remain in place for 1–2 years[23] compared with transabdominal gastrostomy tubes which require replacement in 1–3 months.

Complications

The most common acute complications of endoscopy include aspiration, haemorrhage and perforation;[24] risks associated with sedation/general anaesthesia such as hypoxia, hypotension and aspiration.

Complications of PEG can be major or minor and the overall rate (major and minor) ranges from 0.4% to 22.5%.[25,26] Peritonitis, haemorrhage, aspiration and death are examples of major complications and peristomal wound infection, buried bumper syndrome where gastric part of the tube migrates into the gastric wall, and gastrocolic fistula are some examples of the minor complications.

Table 34.2 illustrates PEG associated complications and Table 34.3 shows tips to avoid or minimize the risk of some of the common complications.

Table 34.2 Major and minor complications of peg tube placement.

Complication	Frequency (%)
Major	
Aspiration	0.3–1.0
Haemorrhage	0–2.5
Perforation of viscera/Peritonitis	0.5–1.3
Necrotizing fasciitis	Rare
Death	0–2.1
Tumour implantation	<1
Minor	
Ileus	1–2
Peristomal infection	5.4–30
Stomal leakage	1–2
Buried bumper	0.3–2.4
Gastric ulcer	0.3–1.2
Fistulous tracts	0.3–6.7
Inadvertent removal	1.6–4.4

Table 34.3 Tips to avoid some of the complication associated with PEG insertion.

Aspiration	Procedure to be performed by experienced operator, avoid excessive sedation and air insufflation
Bleeding	Identify any anatomical variations that can increase risk of bleeding prior to procedure and correct any underlying coagulopathy
Perforation	Careful assessment for any anatomical variations prior to procedure and early recognition of any perforation
Ileus	Observe for few hours prior to start of the feed, use uncapped PEG for decompression if gastric distention occurs
PEG site infection	Prophylactic antibiotics, adequate pre-operative skin prep, appropriate tension between internal and external bumpers, and postoperative PEG site care (with mild soap and water)
Buried bumper syndrome	Avoid excessive tension between internal and external bumpers (position the external bumper in such a way that the tube can be pushed in and out at least 1 cm) and adjust the tension in case of weight gain
PEG site irritation and leakage	Prevent and control infection, adjust the tension between the bumpers and avoid hydrogen peroxide for PEG site care
Gastric irritation	Avoid excessive tension and lateral traction on the PEG tube and consider acid suppression
Oropharyngeal tumour seeding	Perform PEG after surgical removal of primary cancer or use an alternative technique such as Russell technique

CONCLUSIONS

PEG is one of the most commonly performed endoscopic procedures and it is a safe way to provide long-term enteral feeding in selected patients.

To achieve best outcome, factors such as experienced team, appropriate case selection, prevention and early recognition of complications and their management are paramount.

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35

Oral and oropharyngeal squamous cell carcinoma: Pathological assessment of resection specimens and neck dissections

GILLIAN L HALL

CONTENTS

PRESENTATION OF THE SPECIMEN AND TRANSPORT TO THE LABORATORY

- Lay the specimen on a tile or block (heavy card, foam or polystyrene) in the correct anatomical position (Figure 35.1).
- Secure with pins or sutures. Avoid critical areas of the surgical margins. Avoid over-tight sutures (risk of poor fixation and tearing of tissues).
- For modified and selective neck dissections, label the centre of each anatomical nodal level with a tag or suture (Figure 35.1). Submit any additional nodal groups (parapharyngeal, facial, etc.) in separate labelled containers.
- Immerse the specimen fully in fixative. 'Routine' is a formaldehyde-based solution. The volume of fixative should be at least 10 times the volume of tissue.
- Alternatively, divide the neck dissection into separate anatomical levels, mark superior aspect and submit each level in a separate labelled container. Take care not to disrupt integrity of primary tumour when dividing level I from primary tumour in *en bloc* resection specimens.

THE PATHOLOGY REQUEST FORM

- Give complete, accurate details of the name; address (essential for Cancer Registry), gender and date of birth of the patient.
- State the requesting surgeon and hospital, and contact details.
- State the clinical tumour node metastasis (TNM) stage; details of previous histology including the laboratory reference number; and details of previous radiotherapy, chemotherapy or surgery.
- State the type of surgery – curative intent/palliative.
- Describe the clinical features and extent of the lesion, and the extent of the resection, ideally supplemented by annotated photographs or line diagrams (either free hand or pre-printed).
- Give the key to the markers (sutures or tags) used to indicate critical margins, other features of particular interest and the anatomical cervical node levels. In neck dissections, deal with the left and right sides of the neck separately by reference to the anatomical levels included (I–III, I–IV etc.) plus brief details of other structures.

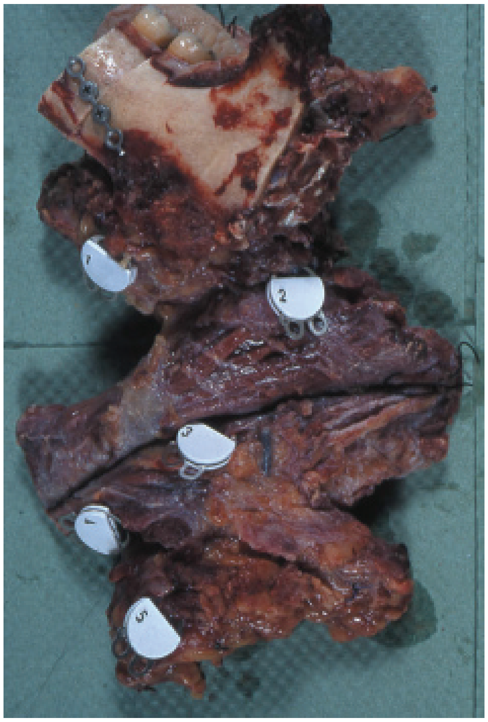


Figure 35.1 Specimen is laid out in the correct anatomical position with tags indicating the centre of each anatomical nodal level.

- Label each pot with the patient's identification and the site/nature of specimen. Use waterproof ink. Check the clarity of pre-printed patient identity labels.
- Give contact details of a designated member of the surgical team if an urgent report is requested or in case of a query.

OVERSIGHT OF LABORATORY PROCEDURES FOR 'ROUTINE' HISTOPATHOLOGICAL STAGING ASSESSMENT

- Macroscopic examination and description of the extent of the surgical resection/dissection specimen and the lesion including measurements ideally supplemented by photography and when appropriate, radiography.
- Surgical margins are painted with Indian ink or a dye to facilitate histological assessment of the proximity of carcinoma to the resection margins.

The primary tumour

- Generally, the specimen is cut into 3–5 mm slices using a coronal plane for specimens from the central and lateral regions of the mouth and a sagittal plane for anterior specimens. If the tumour is close to/involving bone, preliminary assessment of amenable soft tissue margins is often possible prior to decalcification of the bone and the remaining closely-bound soft tissues.

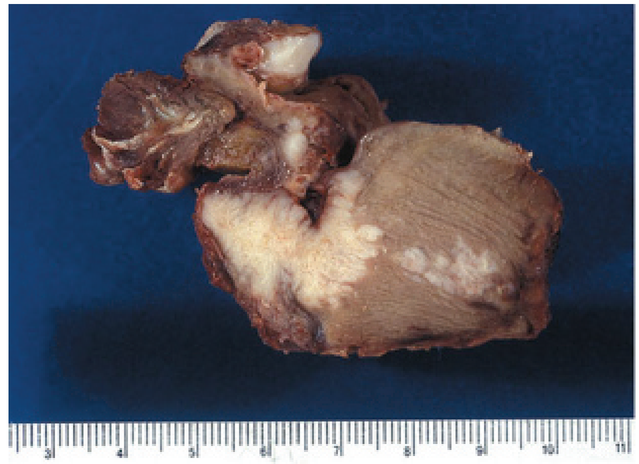


Figure 35.2 Tongue is sliced in a coronal plane. A streak of tumour well-ahead of the main front has resulted in a close deep resection margin. Such streaks may only be present in a single tissue slice and can be missed if the specimen is not sampled thoroughly.

- The tissue slices showing the maximum extent of the tumour (diameter and depth) and the closest resection margins are selected for processing (Figure 35.2). Generally, at least one tissue slice/10 mm of tissue is processed.
- Routine histological assessment is based on one hematoxylin and eosin (HE)–stained section from each tissue block. Step-serial sectioning and immunohistochemistry may be used in difficult cases.
- The maximum dimension (diameter) and depth (reconstructed tumour thickness) is measured to the nearest mm using an optical micrometer to supplement the macroscopic measurements (Figure 35.3). No compensation is made for the tissue shrinkage that occurs during fixation and processing.
- Detailed histological assessment of the body and in particular, the invasive front of the tumour is made.
- The width of the surgical resection margins (mucosal, deep and later on demineralized, bone) is measured to the nearest millimetre using an optical micrometer.

Neck dissections

- The adipose tissue of the fixed specimen is searched by observation and palpation in order to identify all lymph nodes >3–4 mm in size.
- Within each anatomical nodal level, each lymph node is harvested (surrounded by its immediate perinodal fibroadipose tissue).
- Lymph nodes are placed in labelled cassettes, slicing larger nodes as shown in Figure 35.4.
- Ideally, the position of each node is indicated on a line diagram or photograph.

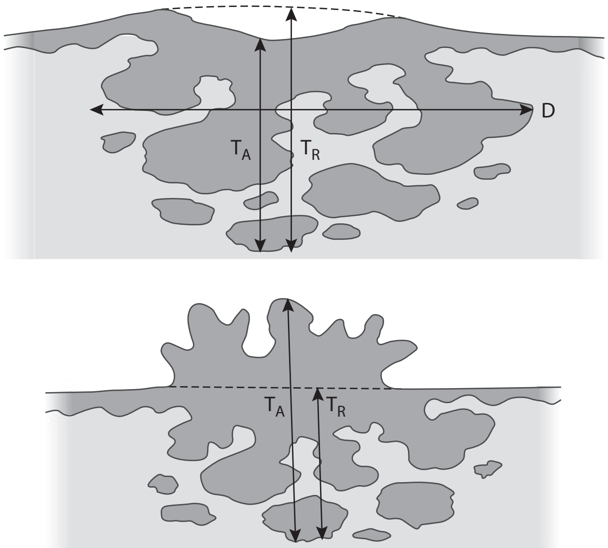


Figure 35.3 T_A – the actual tumour thickness. The more important measurement is T_R – the reconstructed tumour thickness which compensates for surface ulceration or an exophytic component. D represents tumour diameter. It is important to include all satellite tumour islands ahead of the main invasive front in the T and D measurements.

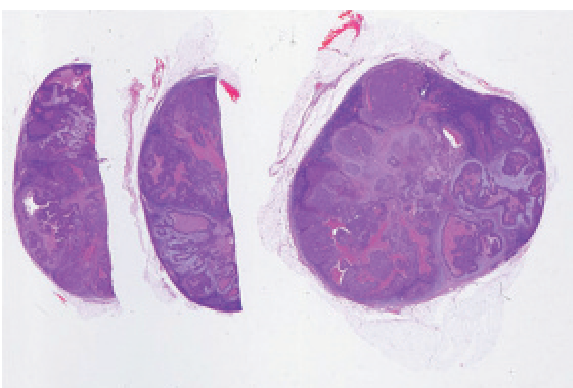


Figure 35.4 Larger lymph nodes are bisected and then one-half is sliced in a perpendicular plane to give several additional nodal profiles which permit a more thorough sampling.

- The 'tissue blocks' are processed by standard means.
- Histological assessment is based on assessment of a single HE-stained section from each tissue block. Step-serial sections are cut in selected cases (such as further assessment of potential micrometastases or early extracapsular spread).

Sentinel node biopsy

- Sentinel nodes that appear negative macroscopically are subject to a more meticulous assessment.
- The node is bisected or sliced into 2.5 mm slices and each slice is processed.
- If node is negative on initial routine HE-stained section, then:
  - Step-serial sections at 150 µm intervals are prepared.
  - One HE-stained section from each step-serial level is assessed.
  - If the HE-stained sections are negative, one slide from each level is stained immunohistochemically for cytokeratin using an antibody such as AE1/3.

HISTOPATHOLOGICAL STAGING – CORE DATA SET

Certain features of mucosal carcinomas have been shown to be related to clinical outcome in terms of local recurrence, regional and distant metastases and survival, and hence, provide information that can help in management and prognosis prediction. Core data sets include only evidence-based features, and to be of value, it is essential that the pathological assessment is made according to standard protocols that include definitions and guidance on practical aspects. The UK Royal College of Pathologists introduced a core data set – outlined in 'Pathological data' – in 1998 with an updated third edition in 2013.

Pathological data – Primary tumour

- Site and subsite.
- Maximum diameter (mm) (see Figure 35.3)
- Maximum depth of invasion/reconstructed tumour thickness (mm) (see Figure 35.3)
- Histological type: squamous cell carcinoma, conventional or subtype
- For conventional SCC: degree of differentiation (well/moderate/poor)
- Subtypes: State subtype
- Invasive front cohesive/non-cohesive (see Figure 3.2)
- Lymphovascular invasion – detected/not detected
- Invasive front neural/perineural invasion – detected/not detected
- Bone/cartilage invasion (detected/not detected) and type (erosive/infiltrative)
- Distance of invasive tumour to mucosal resection margin (mm) and status
- Distance of invasive tumour to deep resection margin (mm) and status
- Overall status of resection margins: clear/close/involved
- Severe epithelial dysplasia: present/not detected
- Severe epithelial dysplasia at resection margin: present/not detected

For oropharyngeal carcinomas only

HPV status	not known	negative	positive
p16 testing	not known	negative	positive
ISH testing	not known	negative	positive

Notes

- In squamous cell carcinoma (SCC) with a multifocal origin, the maximum diameter is based on the overall area of involvement by SCC. Any simultaneous tumour(s) – separated by non-dysplastic mucosa – should be described separately after details of index tumour.
- The histological degree of differentiation (tumour grade) is based on the degree of keratinization, cellular and nuclear pleomorphism, mitotic activity.
- Histological sub-types include verrucous carcinoma; carcinoma cuniculatum; papillary SCC; adenoid (acantholytic) SCC; adenosquamous carcinoma; basaloid SCC; spindle cell carcinoma; giant cell (pleomorphic SCC); undifferentiated carcinoma.
- Prognosis of verrucous carcinoma and carcinoma cuniculatum is generally good since nodal metastases rarely occur. Adenosquamous carcinoma and basaloid SCC of oral cavity, larynx and hypopharynx have a poor prognosis due to early regional and distant metastases. Basaloid type and poorly differentiated tumours of oropharynx are, however, often HPV associated, hence should be assessed at least for p16 positivity (possibly supplemented with in-situ hybridization) which, if positive, is associated with a much more favourable prognosis.
- Lymphovascular invasion is defined as aggregates of tumour cells within endothelial-lined channels or invasion of the full-thickness vessel wall with ulceration of the intima and fibrin deposition/thrombosis.
- Only nerve/perineural invasion at the advancing front is included.
- Optional additional features that may be mentioned include the presence of sialoadenotropism (extension of dysplasia down orifices of minor salivary glands) and ductal invasion.
- Status of resection margins
  - Clear is >5 mm
  - Close is 1–5 mm
  - Involved is <1 mm
  - Involved with histological cut-through is 0 mm

Further details such as the precise site of involvement; apparent explanation (single streak, lymphovascular or neural/perineural invasion ahead of main tumour front, etc.) are optional.

Pathological data – neck dissection

State which levels submitted from left and/or right neck
Type: Standard radical/modified comprehensive/selective
Information on nodal yield, number and size of metastases, and extracapsular spread (see Table 35.1 for example).

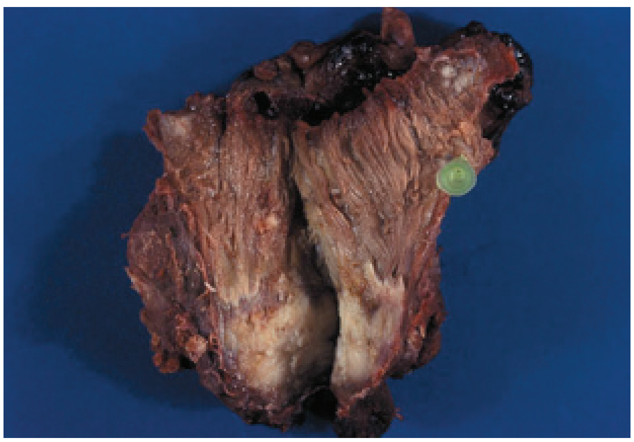
Notes

- 'Size' refers to the total profile diameter of the metastatic deposit not the size of node.
- Matted nodes are described by an estimate of the number of nodes involved and the overall maximum size of largest matted mass.
- ITC denotes 'isolated tumour cells'. These may be detected by detailed histological examination of routinely-stained sections or immunohistochemistry or molecular methods. Assessment for ITC is not routine but may be used for examination of sentinel nodes.

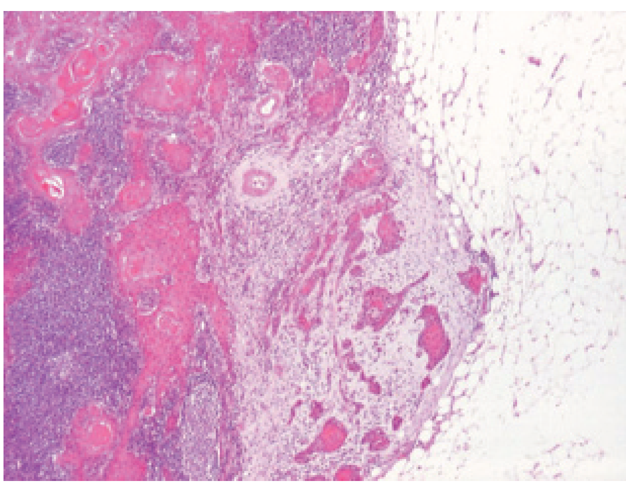
Table 35.1 The grid shows an example of a selective levels I-III dissection.

Nodal level	Total number of nodes examined	Number with metastatic tumour. Specify whether isolated tumour cells (ITC) (<0.2 mm) or micrometastasis (0.2–2 mm)	Extracapsular spread: yes/no
IA	6	3	No
IB	2	0	
IIA	8	2	No
IIB	6	0	
III	5	1 – *micrometastasis*	No
IV			
V			
VI			
Other			
Total number of nodes	27		
Total number of positive nodes	6		
Size of largest metastasis	12 mm		
Extracapsular spread		*Not detected*/present at level I, II, III, IV, V, VI, Other (delete as appropriate)	

- Extracapsular spread ranges from gross invasion of anatomical structures such as muscle (Figure 35.5a) to invasion of perinodal adipose tissue down to pericapsular stromal reaction only detectable on histology (Figure 35.5b). Equivocal cases are upstaged. The extent of extracapsular spread (ECS) (either in mm or by reference to tissues/structures involved) may be stated as an optional detail.
- Other optional extras include presence of embolization/permeation of perinodal lymphatics; presence of evidence of response of tumour to previous therapy (keratin debris/granulomas).
- A radical neck dissection yields an average of 20–30 nodes (and occasionally up to 100) in the absence of previous chemo- or radiotherapy. Salvage neck dissections may yield <10 nodes.



(a)



(b)

Figure 35.5 Extracapsular spread varies widely in extent. (a) Involvement of the sternocleidomastoid muscle. (b) Focal invasion of peri-nodal adipose tissue with a fibrous stromal reaction.

Summary of pathological data

Tumour site: (state with ICD reference)
New primary/recurrence/not known (delete as appropriate)
Histological type (SCC or list subtype)
Pathological stage:
pT ____; pN ____; pM ____; TNM stage grouping _____
Status of resection margin: clear/close/involved

Note:

- The International Union Against Cancer (UICC) TNM clinical and pathological stage categorization criteria are similar.

POTENTIAL INACCURACIES IN PATHOLOGICAL STAGING

- Labelling errors and specimen mix up. Special care is needed when specimen pots have been labelled during preparation of the clinic – any unused pots must be disposed of to ensure specimens are not placed in incorrectly identified pots.
- Sampling errors.
- Surgical (failure to clear all nodes within the drainage area).
- Laboratory (incomplete harvesting of nodes from fixed specimen; inadequate sectioning of individual nodes).
- Inaccuracies in histological detection (failure to notice).
- Errors in histological interpretation.
- ‘Inherent errors’ such as loss of tissue when cutting thin sections.
- Laboratory technical errors and machine malfunction resulting in specimen mix-up or poor quality slides.
- Inadequacies in the written report.
- Secretarial/clerical errors.
- Shortcomings in the UICC TNM staging system such as the use of tumour diameter not thickness, omission of ECS.

Top tips

Accurate pathological assessment of surgical resection specimens requires strict adherence to agreed protocols at each stage:

- Presentation of the specimen and transport to the laboratory
- Submission of an accurate, detailed pathology request form
- Laboratory assessment and dissection of the gross specimen
- Processing and preparation of histological slides
- Histopathological examination
- Presentation of histological findings (core data set, UICC pathological TNM stage)
- Regular ‘risk assessment’ of potential inaccuracies and review/revision of protocols

SUGGESTED READINGS

Woolgar JA. Histopathological prognosticators in oral and oropharyngeal squamous cell carcinoma. *Oral Oncol*. 2006; 42(3): 229–239.

Woolgar J and Triantafyllou A. Neck dissections: A practical guide for the reporting pathologist. *Curr Diagn Pathol*. 2007; 13(6): 499–511.

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36

Access surgery

MADANGOPOLAN ETHUNANDAN, BARRIE T EVANS and DOROTHY A LANG

CONTENTS

ACCESS SURGERY

The excellent blood supply of the craniofacial skeleton allows pedicled or free bone fragments to be moved so gaining access to the skull base and adjacent areas. Tooth bearing maxillary or mandibular bone segments must retain their blood supply and if post-operative radiotherapy is planned pedicled osteotomies are preferable.

CORONAL SCALP FLAP

Indications

The coronal flap provides access to the frontal bone, upper midface, anterior and middle cranial fossa, orbit, temporal and infratemporal fossae in a range of clinical situations.

Applied anatomy

The scalp has five layers (Figure 36.1a and b):

- Skin
- Connective tissue (subcutaneous)
- Aponeurosis (galea) connecting the paired frontalis muscle anteriorly and occipitalis muscle posteriorly
- Loose areolar connective tissue (subgaleal plane)
- Pericranium

Over the temporalis muscle the galea is termed as *temporoparietal fascia*. The subgaleal plane continues laterally over the *temporalis fascia*.

The temporal branch(es) of the facial nerve supplying frontalis are at risk as they run on or within the deep surface of the temporoparietal fascia (Figure 36.1c).

Landmarks of temporal branch(es):

- At least 8 mm in front of the cartilaginous meatus at the zygomatic arch
- At least 1 cm anterior to the upper anterior attachment of the helix
- No higher than 2 cm above the fronto-zygomatic suture (lateral edge of the eyebrow)

Nerve damage is prevented with dissection deep to the temporal fascia beyond these limits (Figure 36.2a and b).

Surgical technique

Along the line of the incision, the hair is either strip shaved or parted. The scalp *above the galea* is infiltrated with lignocaine and 1:200,000 adrenaline.

If a parting is used, the angle of the incision is parallel to the hair follicles to avoid later scar alopecia (Figure 36.3). Alternatively, zig-zag incision is used to prevent parting of the hair along the incision line.

The incision is marked from the anterior attachment of the helix and is carried over the vault of the skull to the opposite side behind the hairline. The incision commences

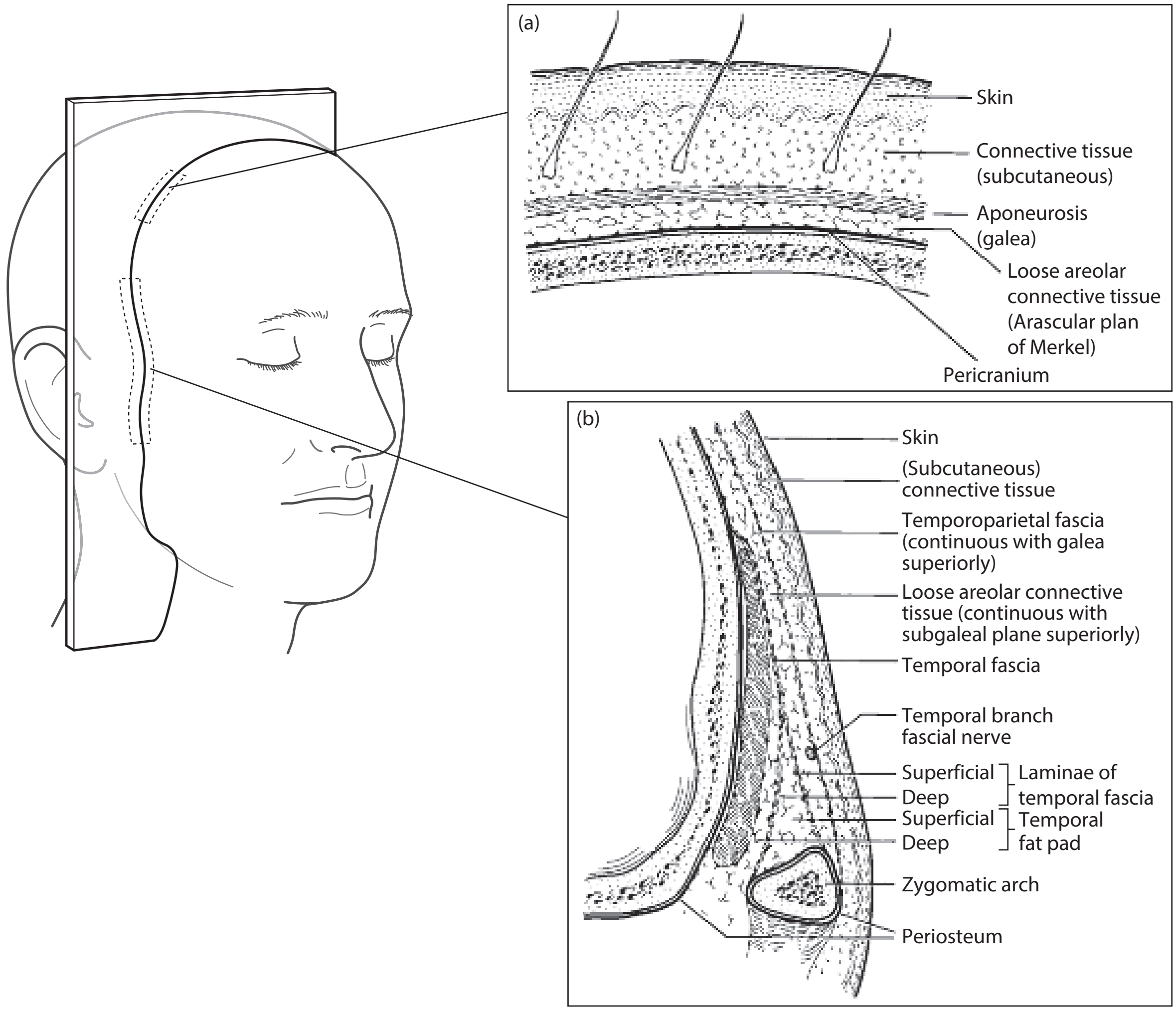


Figure 36.1 Layers of scalp in (a) parietal region and (b) temporal region. Temporal/temporoparietal fascia and the periosteum fuse over the zygomatic arch.

at the vertex and is made through the galea, to the loose areolar tissue (avascular plane of Merkel) – lifting the first three layers as a 'unit' and extended laterally to the superior temporal line (Figure 36.4).

Blunt scissors or a brain retractor can be used to undermine the incision line along this plane, down to the root of the helix and with the brain retractor in situ, the incision is made down to it. This allows rapid elevation of the flap, without inadvertent damage to the underling temporal fascia/temporalis muscle.

The incision is made with a scalpel or Colorado needle and haemostasis achieved with bipolar diathermy. Dissection is carried forward in the subgaleal plane. Approximately 3 cm above the superior orbital rim the pericranium is incised and the dissection continued subperiosteally. Resistance is then met at three points:

- The fronto-zygomatic suture.
- The supra orbital neurovascular bundle is freed from its bony canal with an osteotome (Figures 36.5 and 36.6).
- The fronto-nasal suture.

A midline vertical incision in the periosteum aids exposure of the nasal bones and frontal process of the maxilla.

Detachment of the medial canthal tendon from the anterior lacrimal crest gives unrestricted exposure of the medial orbit to the optic canal, and the orbital floor to the infraorbital nerve.

The medial canthal tendon may be 'tagged' through the periosteum with a suture for later reattachment to a microplate (Figure 36.7). Subperiosteal dissection medially is now possible as far the floor of the nose.

To expose the temporomandibular (TM) joint, zygoma and lateral orbit, the skin incision is extended inferiorly to just below the cartilaginous meatus either in a naturally occurring pre-auricular skin crease or endaurally around the tragus (Figure 36.8a and b). The dissection is taken forward and medially following the cartilaginous meatus. Superiorly the skin flap is elevated off the temporalis fascia by blunt dissection.

At the upper attachment of the helix, the temporalis fascia is incised – about 1 cm above the zygomatic arch,

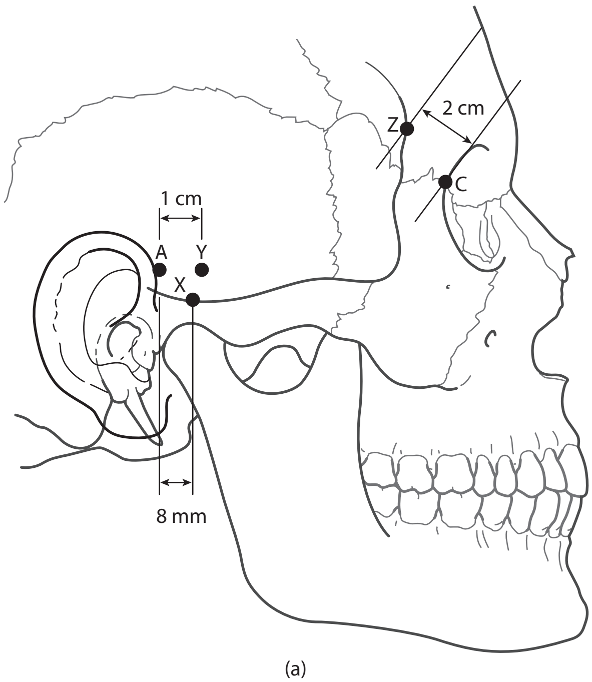


Figure 36.2 (a) The outer limits of the temporal branch(es) of the facial nerve. (b) The temporal branch of the facial nerve is superficial to the temporal fascia anterior to the line A-B.

Figure 36.3 With the hair parted the incision is parallel to the hair follicles.

and angled forward to connect with the supraorbital periosteal incision 3 cm above the superior orbital rim (Figure 36.9). A pericranial flap could be easily incorporated, by extending the pericranial incision superiorly to the required length, between the superior temporal lines, as an extension of the temporalis fascia incision (Figure 36.10a and b).

The incision in the temporalis fascia is then taken vertically down to the level of the zygomatic arch – easily palpated immediately above the cartilaginous meatus (Figure 36.11).

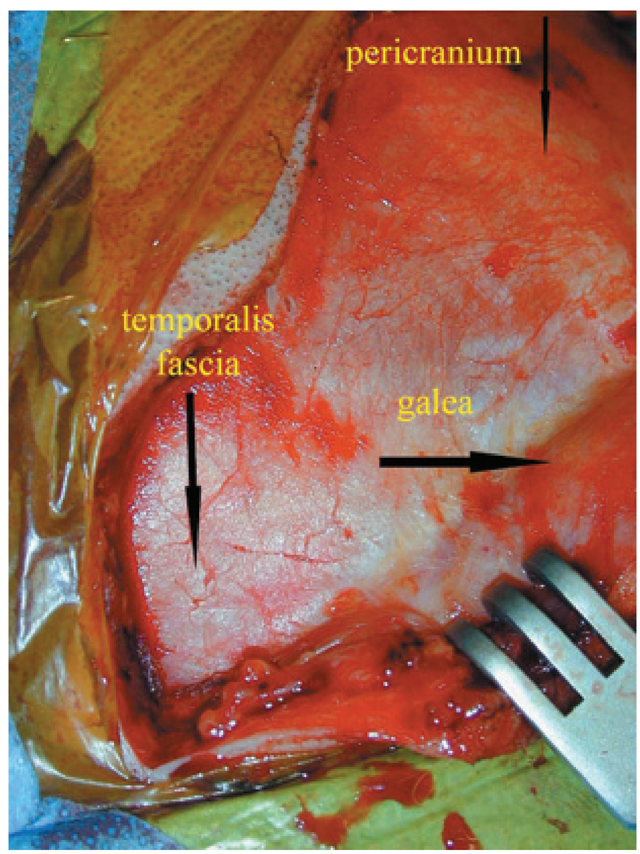


Figure 36.4 The first three layers of the scalp lift as a single unit.

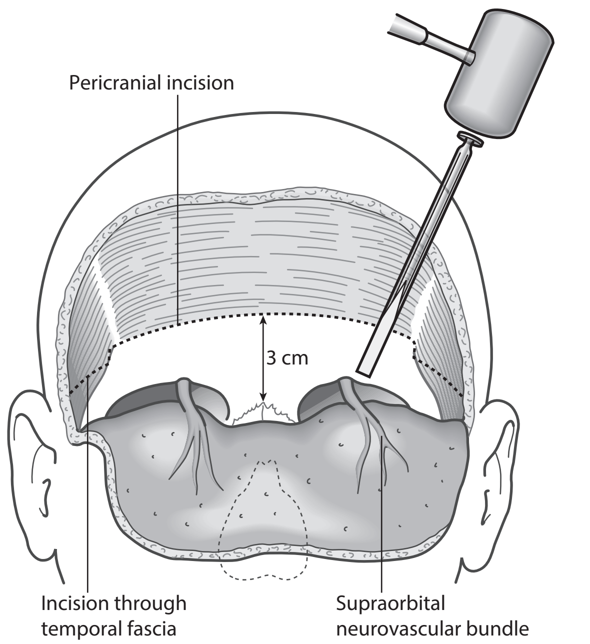


Figure 36.5 Supraorbital neurovascular bundle freed with osteotome.

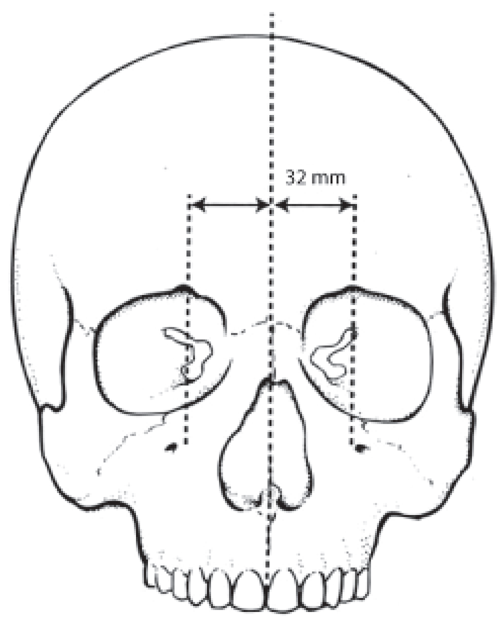


Figure 36.6 Average distance supraorbital notch/foramen from midline 32 mm (range, 15–38 mm).

The periosteum over the zygomatic arch is incised and turned forward with the temporalis fascia, temporoparietal fascia containing the temporal branch(es) of the facial nerve, and the skin – as a single flap. Subperiosteal dissection is continued anteriorly to expose the zygomatic arch, body of the zygoma and lateral orbital rim (Figure 36.12). Retraction of the temporalis muscle provides additional exposure of the temporal fossa and superior limit of the infratemporal fossa.

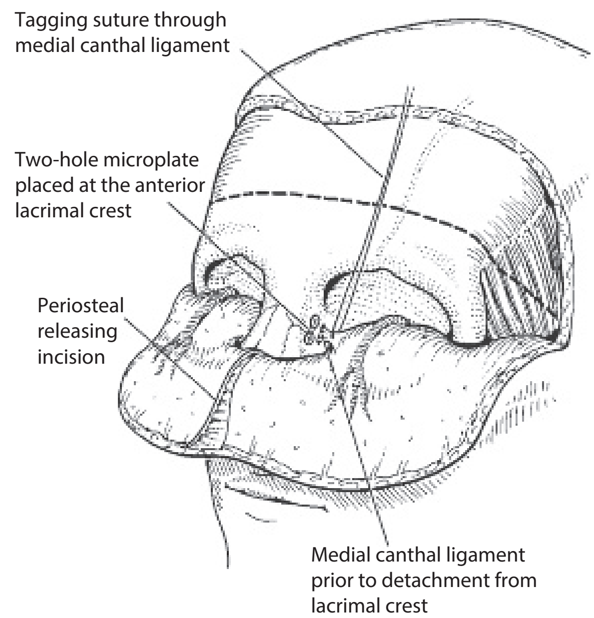


Figure 36.7 Midline vertical releasing periosteal incision to aid exposure of nasal bones. Medial canthus 'tagged' with suture for later attachment to microplate.

The periosteum is freed over the lateral and inferior orbital rim, detaching the lateral canthal ligament. Deep circumferential subperiosteal orbital is now easily achieved.

The extent of subperiosteal exposure possible with the coronal scalp flap is demonstrated in Figure 36.13.

Closure of the galea is essential.

Midface procedures

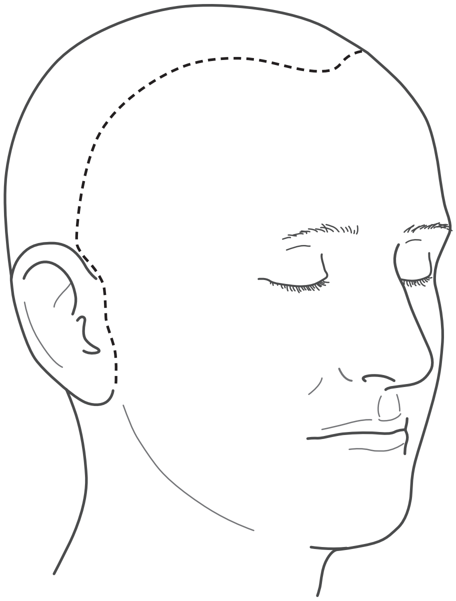
- Transfacial
- Transoral (Le Fort I) approach – this is familiar to all orthognathic surgeons and the surgical technique will therefore not be discussed.

Transfacial approaches

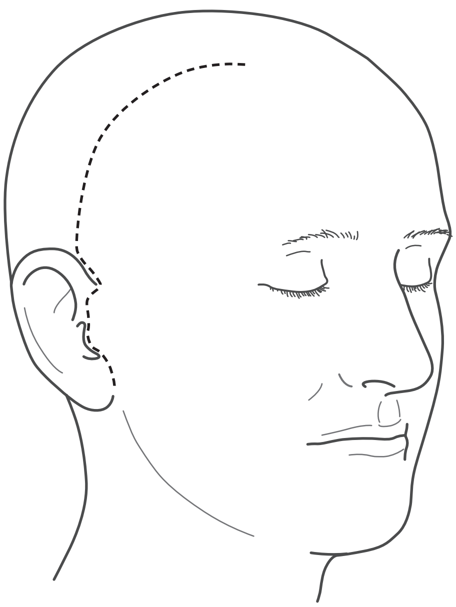
These approaches mobilize the midfacial skeleton via a facial incision – ideally pedicled to the soft tissues. The maxillary and nasal swing procedures are the 'standard' approaches – they can be combined, modified or extended.

These approaches access the following:

- Nasal cavity, maxillary, ethmoid and sphenoid sinuses
- Soft palate and nasopharynx
- Infratemporal fossa/parapharyngeal space
- Clivus
- Upper cervical spine



(a)



(b)

Figure 36.8 (a) Incision in skin crease; (b) following the tragus.

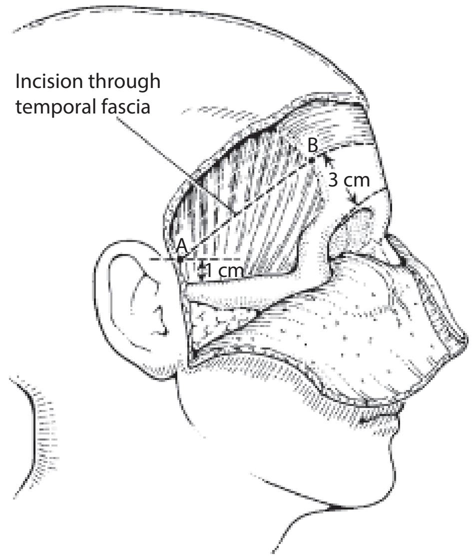
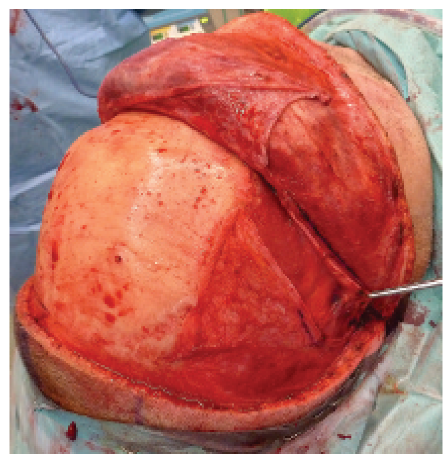


Figure 36.9 The incision through the temporal fascia is made along line A-B (see Figure 36.2b) to ensure preservation of the temporal branch of the facial nerve. Complete exposure of the temporomandibular (TM) joint and the entire zygoma is possible without damage to the temporal branch of the facial nerve.



(a)

(b)

Figure 36.10 (a and b) Incorporation of a pericranial flap as an extension of the temporal fascia incision.

MAXILLARY SWING: PEDICLED OSTEOTOMY OF THE MAXILLA/HARD PALATE

Top tips

- Step soft tissue and bone cuts so wounds lie on sound bone.
- Modified soft tissue incision on palate around gingival margins prevents palatal fistulae.
- Secure mobilized maxilla to cheek soft tissues with gauze swab and 0 silk sutures.
- Palatal splint ± occlusal splint the simplifies fixation of maxilla on completion.

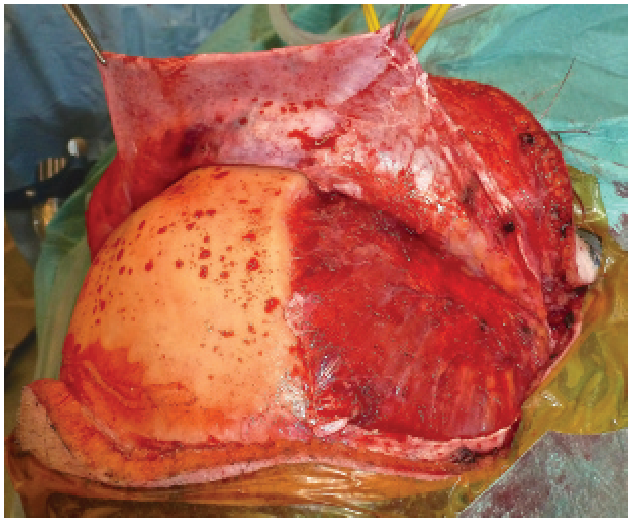


Figure 36.11 Inferior extension to the zygomatic arch.

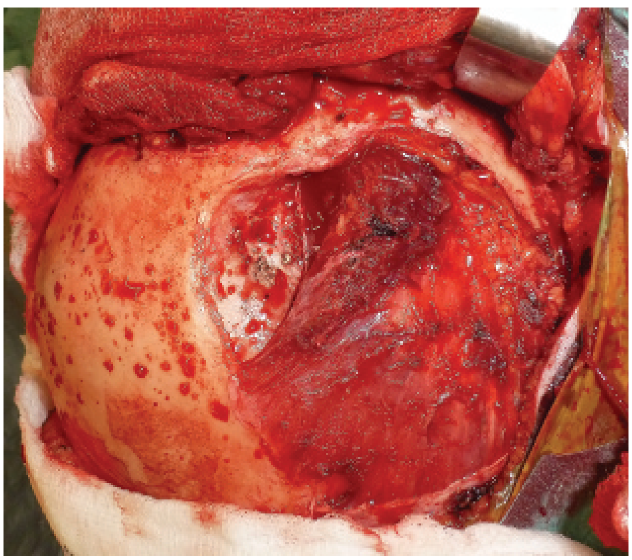


Figure 36.12 Exposure of the orbital rim, zygoma, zygomatic arch and temporal fossa.

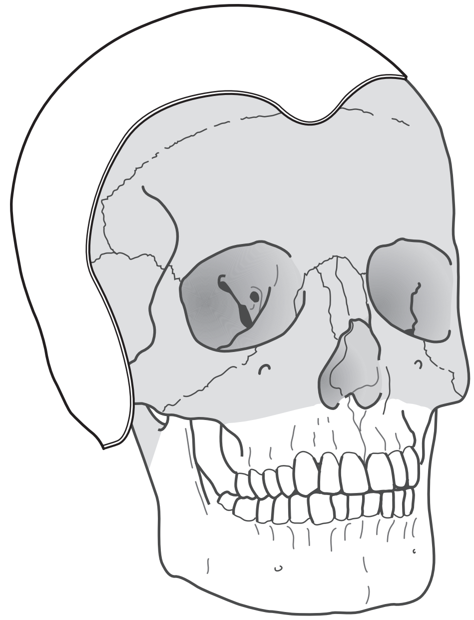


Figure 36.13 Exposure possible with a coronal flap.

Figure 36.14 Weber–Fergusson incision with lateral eyelid incision.

Incision

A modified Weber–Fergusson incision is made with a lateral eyelid extension, respecting the nasal subunits (Figures 36.14 and 36.15). A 'V' shaped notch can be incorporated in the mucosal aspect of the upper lip and alar rim, to help accurate localization of the flap. Subperiosteal stripping is minimized to retain the maximum blood supply to the bone segments.

The incision is taken vertically through the alveolar mucosa and attached gingiva between the upper central incisors. The palatal incision is in the midline extended laterally at the junction of the hard and soft palate behind the maxillary tuberosity (Figure 36.16a and b).

The authors preferred approach is to make the incision around the gingival margins of the teeth, extending from the canine tooth on the opposite side to the pterygoid hamulus, deliberately sectioning the greater palatine neurovascular bundle on the side of the osteotomy. The nasopalatine bundle is preserved if the bone cut is between the central and lateral incisor teeth. The palatal soft tissues are elevated to the opposite side (Figure 36.17). This incision avoids the risk of palatal fistulae.

Bone cuts

The bone cuts are made with fine saws or a fissure burr and completed with osteotomes.

Figure 36.15 Modified Weber–Fergusson incision respecting the nasal subunits, with a potential for medial glabella extension (dotted lines).

The mucoperiosteum of the floor/lateral wall of the nose is elevated and the bone cuts made are as follows:

- Between the central and lateral incisor teeth, continued paramedially through the length of hard palate into the nasal floor.
- Laterally from the piriform fossa, below the inferior turbinate (preserving the nasolacrimal duct) through the anterior maxilla inferior to the infraorbital nerve through the zygomatic buttress back to the pterygoid plates. The infraorbital nerve is sectioned at the infraorbital foramen as it prevents lateral retraction of the maxilla. The nerve ends may be tagged for later anastomosis.
- The bone cut posterior to the zygomatic buttress is angled downwards and may be made either with a fine osteotome or reciprocating saw, to reduce soft tissue stripping.

The maxilla is pre-localized with bone plates:

- Above the incisor teeth anteriorly
- At the frontal process of the maxilla
- On the zygomatic buttress

The maxilla and pterygoid plates are separated with a curved pterygoid chisel placed through a small vertical buccal incision (Figure 36.18).

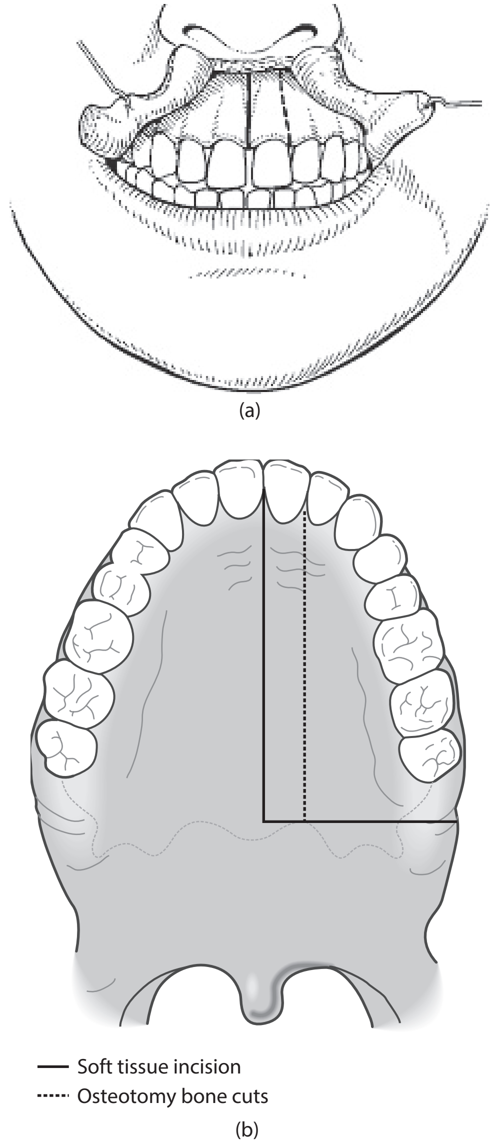


Figure 36.16 (a and b) Stepped soft tissue and bone cuts avoid later wound dehiscence/fistulae.

The maxilla is then outfractured, pedicled to the soft tissues of the cheek. The maxilla can be secured to the soft tissues with 0/silk sutures over a gauze swab (Figure 36.19).

Following nerve division, wide lateral retraction of the maxilla exposes the soft palate, nasopharynx and infratemporal fossa (Figure 36.20).

The buccal pad of fat is within the operative field and immediately available for reconstruction as a pedicled flap. The coronoid process and the attached temporalis tendon may impede access to the infratemporal fossa. A coronoidectomy will improve access and has the added benefit of reducing post-operative trismus.

When closing an occlusal splint may be used if the bite is not 'positive'. The palatal soft tissues are covered with an acrylic cover plate wired to the standing teeth. Closure of the palatal tissues is therefore not needed. The plates and screws are reapplied.

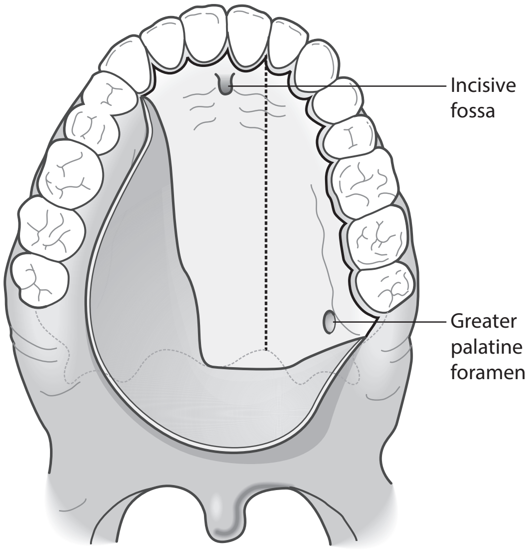


Figure 36.17 Alternative (favoured) palatal incision, with the incisive and greater palatine foramina highlighted.

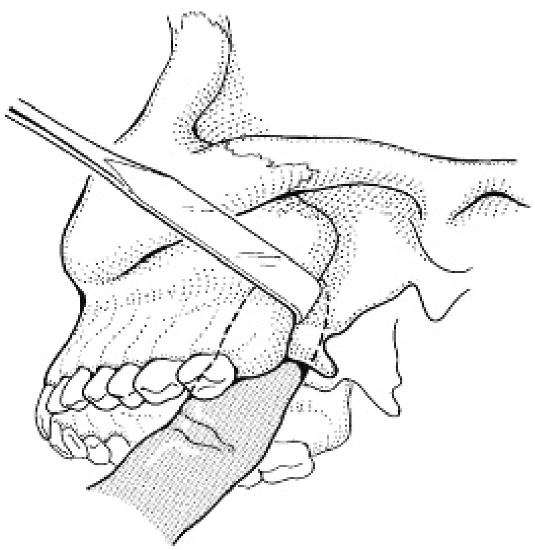


Figure 36.18 Separation of the pterygoid plates with curved osteotome.

The maxilla is frequently mobile to a degree at the completion of surgery. The palatal cover plate can be left in situ for 6–8 weeks or until maxillary stability is achieved.

NASAL SWING: PEDICLED OSTEOTOMY OF THE NASAL BONES AND FRONTAL PROCESS OF THE MAXILLA

Access to lesions in the nose, ethmoid and sphenoid sinuses. Unlike the lateral rhinotomy it has the advantage of avoiding bone resection.

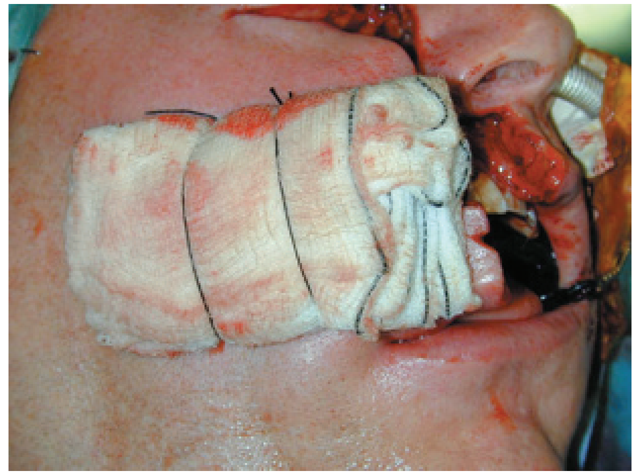


Figure 36.19 Mobilized maxilla secured to facial skin with sutures.

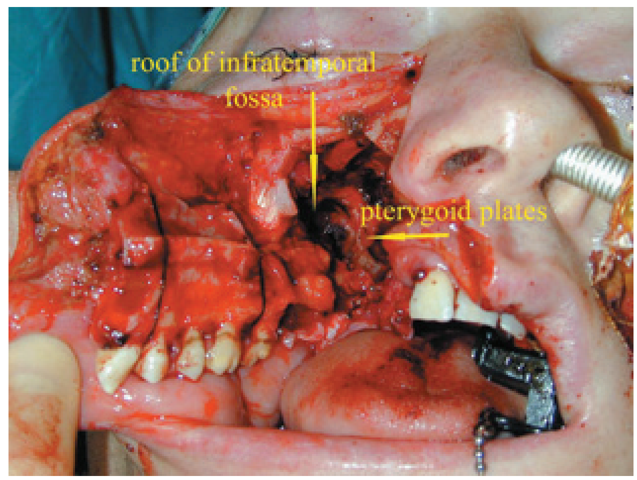


Figure 36.20 Maxilla swung laterally to access infratemporal fossa.

Top tips

- Both the frontal process of maxilla and nasal bones moved.
- Extend soft tissue incision slightly laterally on the face to prevent bone/soft tissue cuts being in line.
- Moist tonsillar swab in opposite nostril when completing the cut through the cartilaginous nasal septum.

Incision

A modified Weber–Fergusson incision is made respecting the nasal subunits and allowance is made for a transverse medial extension along the glabella skin crease (Figure 36.15). The soft tissues are retracted laterally and superiorly to expose the nasal bones, frontal process of the maxilla and the piriform rims. Exposure of the contralateral nasal bones is achieved by undermining. Bone cuts are

made with a saw/fine bur, after placement of localizing plates. The contralateral nasal osteotomy is carried out with fine osteotomes, if necessary, through separate stab incisions. The underlying nasal mucosa and soft tissue along the piriform rim are released with a diathermy.

The soft tissue incisions and the bone cuts are stepped. The nasal bones are pre-localized with low-profile bone plates (Figure 36.21).

The nasal septum restricts complete lateral retraction. A damp tonsillar swab is placed in the opposite nostril and the cartilaginous nasal septum divided vertically in line with the osteotomy bone cuts. The septal cartilage is divided with a cutting diathermy set on 'coagulation' – the damp swab in the opposite nostril prevents accidental trauma to the mucosa of the contralateral lateral nasal wall and the facial skin on the opposite side. The 1-cm strut of nasal cartilage is preserved along the dorsum and columella to prevent collapse in the distal nose that prevents later nasal collapse. The nasal bones and the nasal soft tissues are retracted to the opposite side (Figure 36.22).

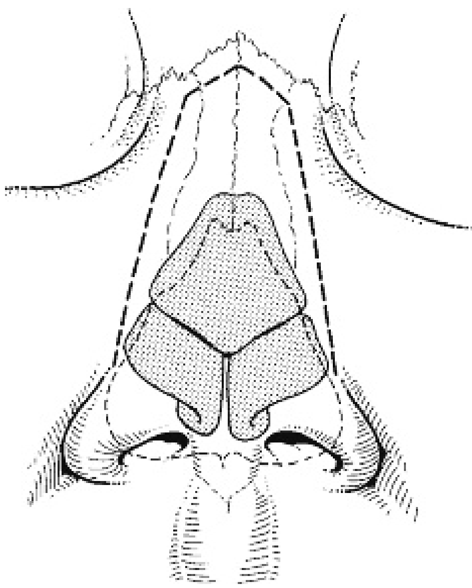


Figure 36.21 Nasal osteotomy bone cuts.

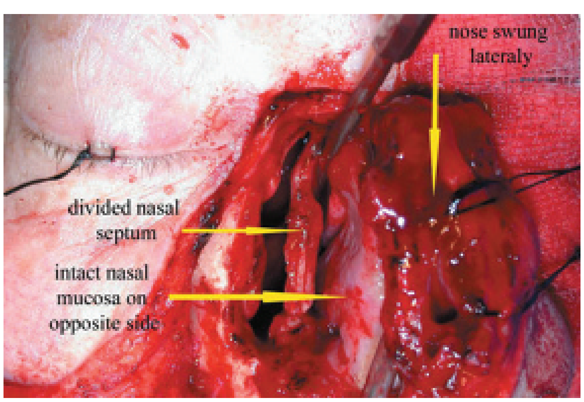
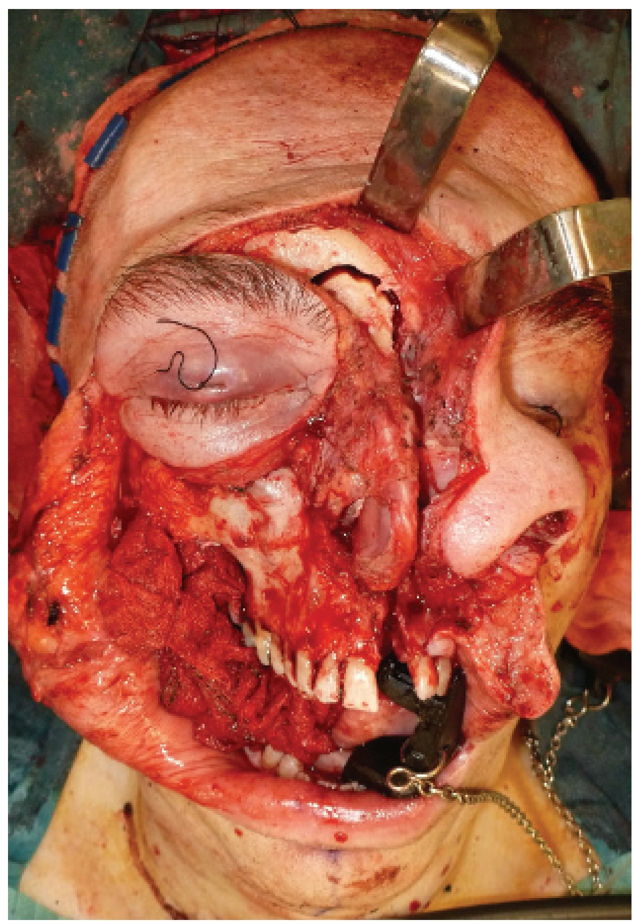


Figure 36.22 Nasal swing incorporating frontal process of maxilla and nasal bones.

A soft tissue nasal swing or soft and hard tissue nasal swing can be combined with a larger midface/craniofacial resection for pathologies involving adjacent structures (Figure 36.23a and b).

The nasal swing links readily with a frontal craniotomy for resection of pathology that also involves the central compartment of the anterior cranial fossa.

(a)



(b)

Figure 36.23 (a and b) Incorporating soft tissue nasal swing/nasal osteotomy with a craniofacial resection.

The transfacial approaches may also be combined with mandibular osteotomies for further access.

Per oral

A significant proportion of oral lesions can be excised 'per orally'. This access is principally dependent on the location and size of the lesion and the status of the dentition and mouth opening. An appropriate-sized mouth prop/gag along with cheek and tongue retractors are utilized to provide the necessary access (Figure 36.24a and b).

Soft tissue lip split

Soft tissue lip split can provide excellent access to the posterior buccal mucosa and mandible, for lesions that cannot be safely excised through a per-oral approach. The principle disadvantage of the approach is the need to often sacrifice the mental nerve; this must be weighed against improved access. This is not a consideration if the inferior alveolar nerve is sacrificed in the subsequent resection.

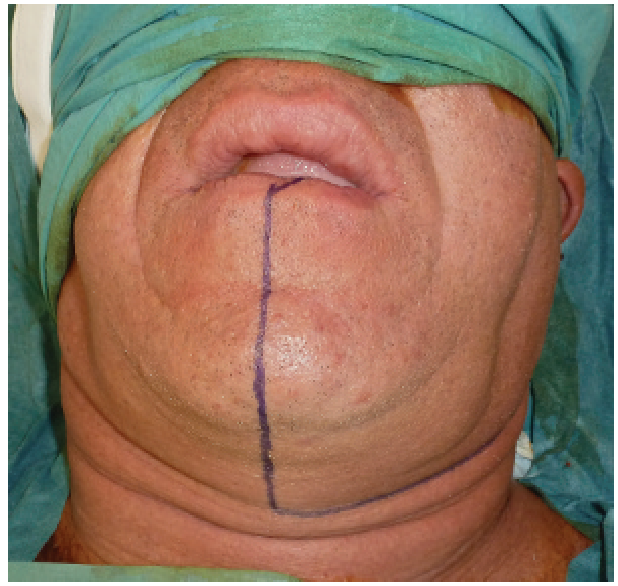
A full-thickness vertical incision is made through the midline of the lower lip and extended inferiorly across the midline of the chin/upper neck, continues with an appropriately placed low neck skin crease incision. A 'V' can be incorporated in the mucosal aspect of the lower lip to facilitate accurate approximation (Figure 36.25a).

The cosmetic outcome with a midline chin incision is excellent and reduces the risk of numbness and ischemia

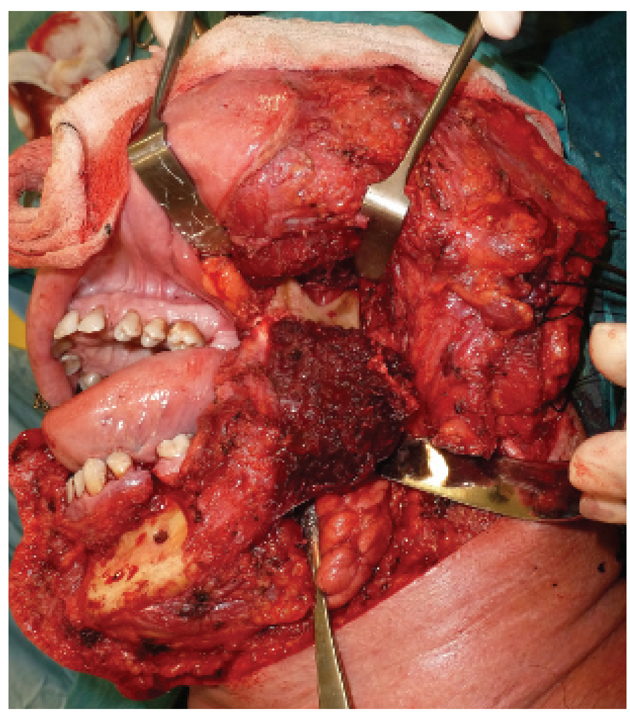
(a)

(b)

Figure 36.24 (a and b) Per oral resection with appropriate retraction and mouth opening.



(a)



(b)

Figure 36.25 (a) Skin markings for soft tissue lip split; (b) exposure obtained.

of the ipsilateral chin, associated with a curvilinear incision along the mental fold.

The neck skin flap is raised in the subplatysmal plane up to the lower border of the mandible, taking care to avoid damage to the marginal mandibular branch of the facial nerve. The cheek flap is elevated by detaching the platysma from the lower border of the mandible in the immediate supraperiosteal plane. More posteriorly, the dissection can be extended superficial or deep to the masseter muscle.

Intra-oral soft tissue incisions are principally determined by the location of the tumour (Figure 36.25b).

Visor

A visor flap can be utilized for lesions in the anterior floor of mouth and mandible and can be combined with bilateral neck dissections. The incision is marked at an appropriate low-neck skin crease and extends from one mastoid tip to the other (Figure 36.26a). The skin flaps are raised in the subplatysmal plane up to the lower border of the mandible, taking care to preserve the marginal mandibular branch of the facial nerve. The periosteum is incised along the lower border of the mandible and a mucoperiosteal flap elevated, taking care to identify the mental nerves (Figure 36.26b). Intra-oral mucosal incisions are determined by the location of the lesion and the mental nerves are often sacrificed to obtain further access or adequate margins.

The skin flaps are retracted cephalad with rubber drains (Figure 36.26c). Resection of the lesions in the anterior floor of mouth along with the mandible results in loss of attachment of the tongue to the mandible (Figure 36.26d). It is essential that the genioglossus and geniohyoid muscles are re-attached to the reconstructed mandible to prevent the tongue falling back (Figure 36.26e). The advantage of this incision is the avoidance of a lip split facial scar, which needs to be weighed against the risk of damage to the mental and marginal mandibular branch of the facial nerves bilaterally.

TRANSMANDIBULAR APPROACHES

Top tips

- When accessing the oral cavity the osteotomy bone cut is in the incisor region.
- A straight bone cut is used.
- No incision is made through the lingual mucoperiosteum – the soft tissues are simply elevated off the lingual aspect of the mandible adjacent to the osteotomy.
- For combined access to the oral cavity and infratemporal fossa, an extended mandibular swing is appropriate; a lip split is necessary.
- For wide access to the infratemporal fossa/parapharyngeal space without the need to involve the mouth, a lip split is avoided.

Mandibular swing

The technique provides excellent access to the floor of the mouth, mid and posterior third of tongue, tonsillar fossa, soft palate, oropharynx including the posterior pharyngeal wall, supraglottic larynx and medial aspect of the mandibular ramus. Extended posteriorly it provides equally good access to the infratemporal fossa, and the parapharyngeal space with vascular control.

There are three separate elements:

1. Division of the lower lip and chin
2. Division of the mandible in the incisor region
3. Elevation of the soft tissues off the lingual aspect of the mandible

Mandibular continuity is restored on completion.

Surgical technique

A full-thickness vertical incision is made through the midline of the lower lip and extended inferiorly across the midline of the chin/upper neck, continues with an appropriately placed low neck skin crease incision. A 'V' can be incorporated in the mucosal aspect of the lower lip to facilitate accurate approximation (Figure 36.27a and b).

The cosmetic outcome with a midline chin incision is excellent and reduces the risk of numbness and ischemia of the ipsilateral chin, associated with a curvilinear incision along the mental fold.

The neck skin flap is raised in the subplatysmal plane up to the lower border of the mandible, taking care to avoid damage to the marginal mandibular branch of the facial nerve. Intra-orally, the incision through the labial mucosa and attached gingiva is stepped, so that it does not lie directly over the planned osteotomy. The periosteal elevation and mentalis muscle stripping should to restricted to allow identification and protection of the mental nerve and placement of the plates (Figure 36.28).

No vertical incision is made through the lingual mucoperiosteum. The soft tissues are simply elevated off the lingual aspect of the mandible adjacent to the osteotomy. A full-thickness lingual mucoperiosteal flap is subsequently elevated off the lingual aspect of the mandible through a crevicular incision, when the mandible is retracted laterally (Figure 36.29). The incision through the oral tissues is adjacent to the pathology – allowing for sufficient tumour clearance.

The osteotomy is preferably performed in the incisor region for tumours involving the oral cavity. Non-union is rare at this site even with post-operative radiotherapy (Figure 36.30). Osteotomy in the premolar region anterior to the mental foramen is only employed by the authors to access tumours in the infratemporal fossa/parapharyngeal space when avoiding a lip split incision (see Figure 36.30).

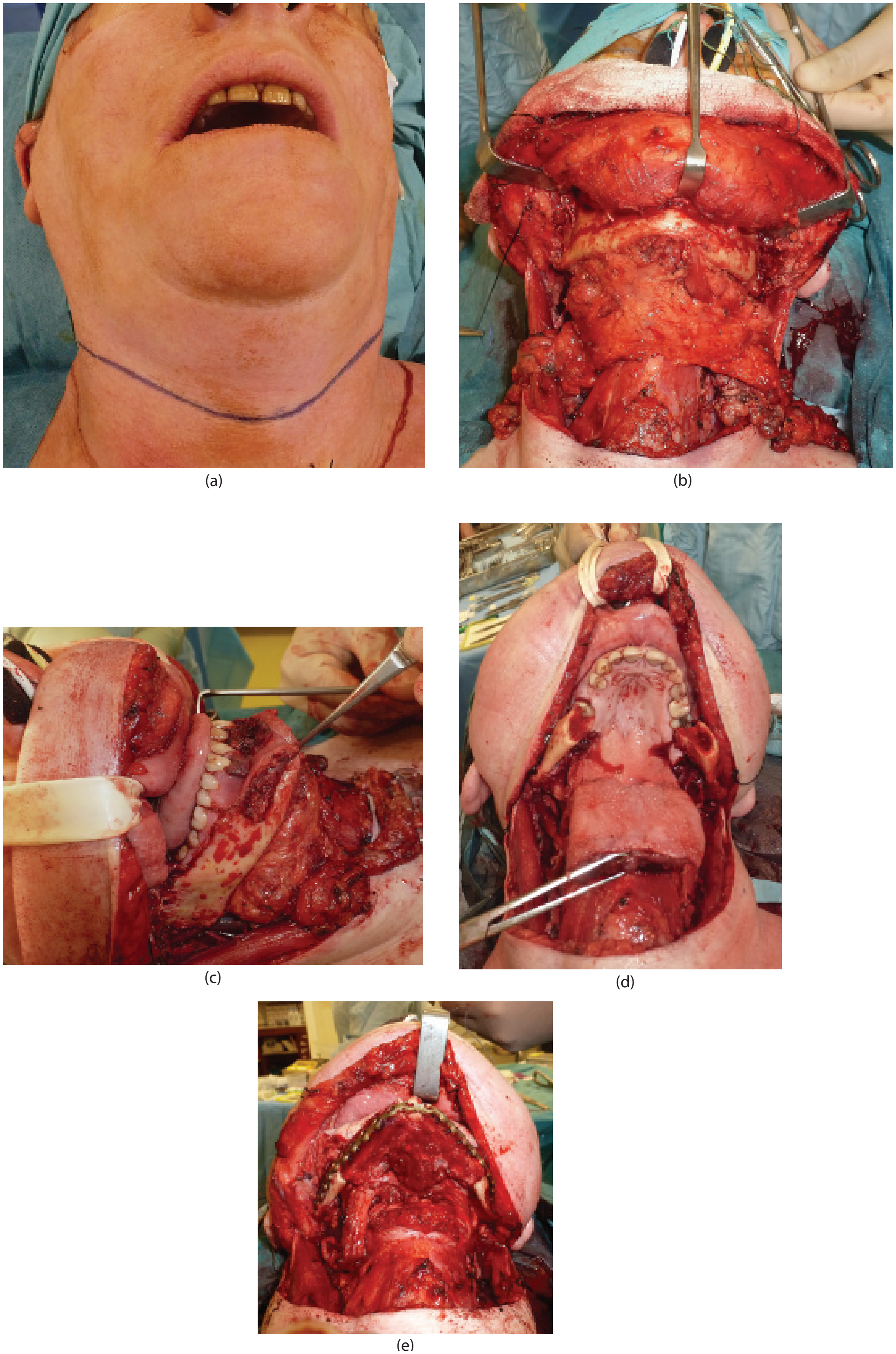
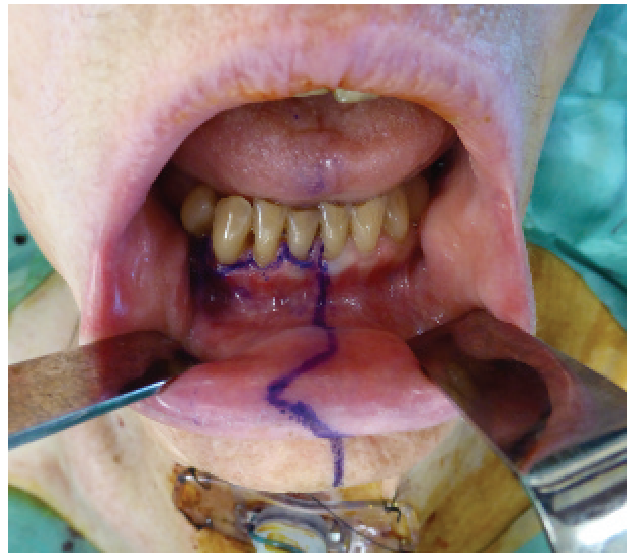


Figure 36.26 (a) Skin markings for a visor flap. (b) Skin flaps raised to lower border of mandible. (c) Exposure obtained. (d) Lack of tongue attachments following resection of anterior mandible. (e) Composite fibula free flap reconstruction with re-attachment of the tongue.

(a)



(b)

Figure 36.27 (a and b) Soft tissue incisions for lip split mandibulotomy (a) skin marking; (b) mucosal markings.

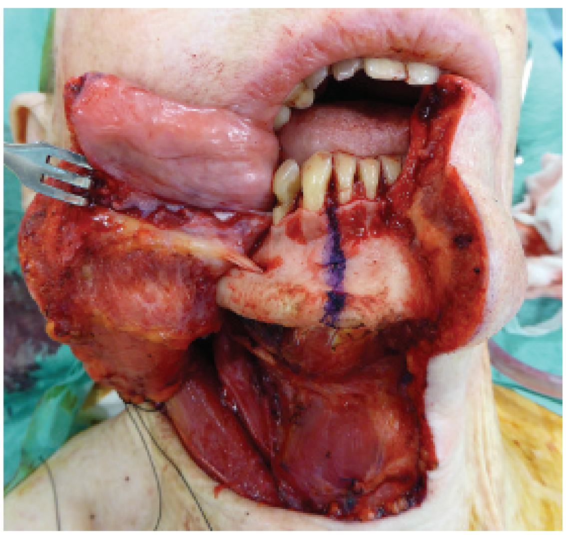


Figure 36.28 Mandibulotomy bone cut markings between lateral incisor/canine teeth.

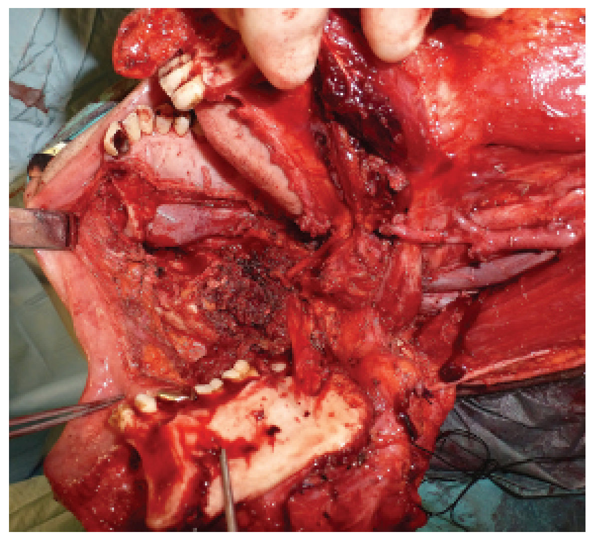


Figure 36.29 Mandible swung laterally – intact lingual periosteum.

The mandible is divided with a fine saw blade between the roots of the incisor teeth. Occasionally, an incisor tooth is removed if there is insufficient room between the dental roots for the bone cut. Prior to division the mandible is pre-localized with bone plates across the osteotomy bone cut – these are removed and replaced on closure.

The osteotomy bone cut is a simple straight line in all cases. A stepped bone cut aids neither fixation nor bone union.

Following division the mandible is gently retracted laterally – the lingual soft tissues including the mylohyoid muscle are stripped off the mandible.

Extended mandibular swing

By stripping the medial pterygoid and the stylomandibular ligament off the medial aspect and angle of the mandible, respectively; further lateral and superior mandibular retraction is possible and provides wide access to the infratemporal fossa and parapharyngeal space (Figure 36.31).

For lesions in the tongue and floor of the mouth, the mandibulotomy access is very similar, but the lingual soft tissue margins are determined by the location of the tumour (Figure 36.32a and b).

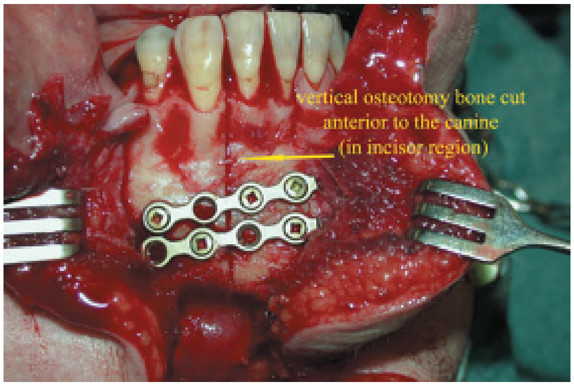


Figure 36.30 Mandibulomy with fine saw cut and pre-localized plates.

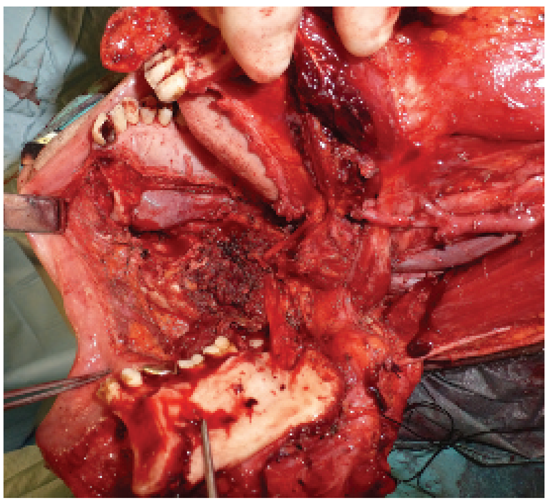


Figure 36.31 Exposure with extended mandibular swing following detachment of medial pterygoid and stylomandibular ligament.

Angle osteotomy and double mandibular osteotomy avoiding lip split

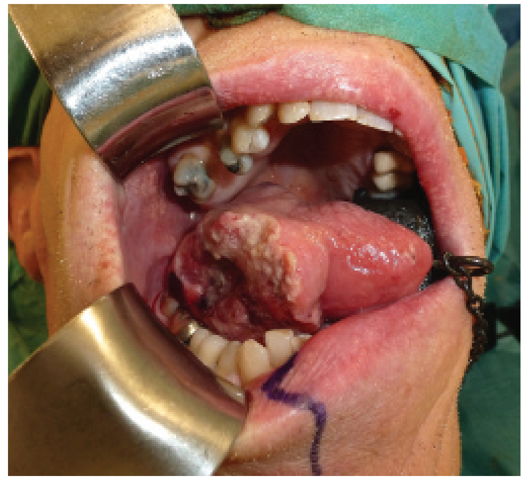
For tumours confined to the infratemporal fossa/parapharyngeal space without the need to involve the oral cavity, the approach is determined by the following:

- Size of tumour
- Need to preserve lower lip sensation

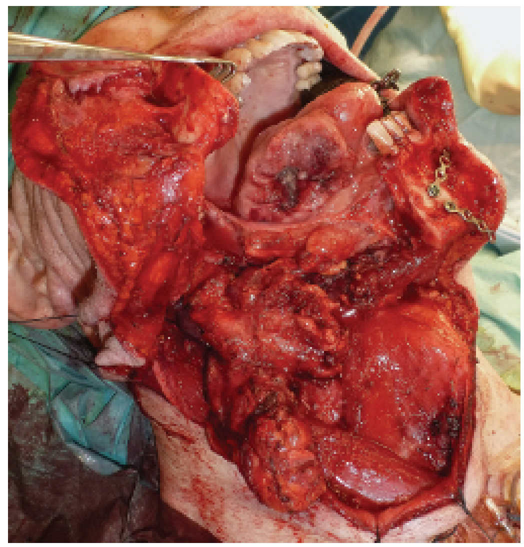
For smaller tumours, very limited access is provided by simply elevating the mandibular angle or by detaching the stylomandibular ligament at the angle of the mandible and dislocating the mandibular condyle anteriorly (Figure 36.33a and b).

If greater access is needed then one of the following procedures is used.

For larger tumours:



(a)



(b)

Figure 36.32 (a and b) Exposure of tongue lesion following mandibular swing. (Pre-localized plates left in situ.)

- If lower lip sensation is already lost or will be lost in the resection, a simple angle osteotomy sectioning the inferior dental (ID) bundle is satisfactory (Figure 36.34).
- If lower lip sensation is to be preserved, a lip split can be avoided by combining a vertical ramus osteotomy behind the lingula with an additional osteotomy anterior to the mental foramen – usually between the canine and the first premolar as described by Smith et al.[1] (Figure 36.35a and b).

In each case, the mandible is pre-localized with bone plates. It is possible to trace the internal carotid artery to the skull base adequately with both approaches.

A horizontal osteotomy of the mandibular ramus as suggested by Attia et al.[2] is avoided as the area of bone contact is limited with this technique.

If resection of the floor of the middle fossa is required in skull base procedures, additional superior access is

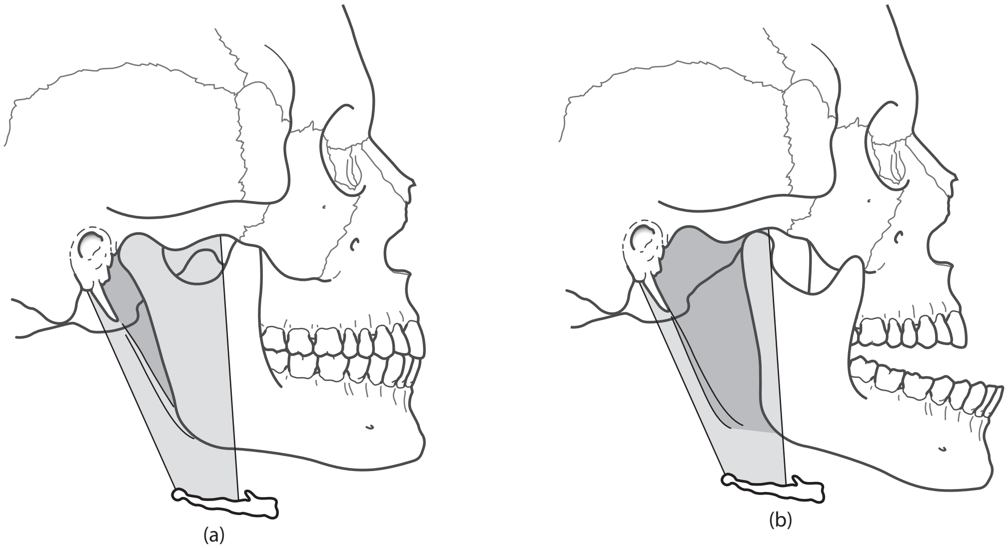


Figure 36.33 (a and b) Limited access to retromandibular and parapharyngeal space by anterior mandibular dislocation and division of the stylomandibular ligament.

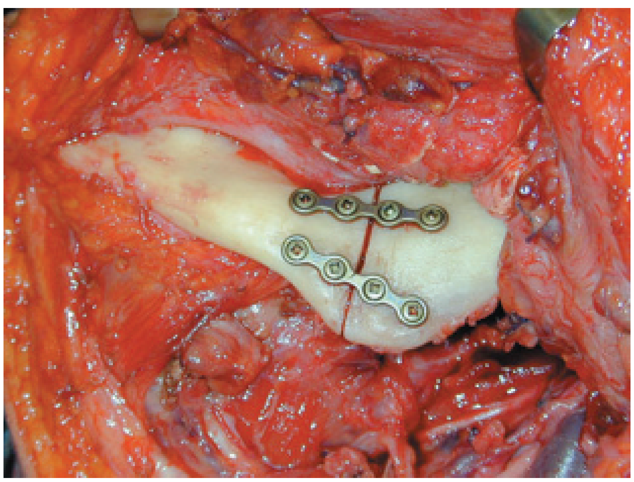


Figure 36.34 Osteotomy through the angle and inferior dental (ID) neurovascular bundle.

easily achieved by mobilizing the zygoma (see section 'Transzygomatic Approaches').

TRANSZYGOMATIC APPROACHES

Top tips

- The lateral aspect of the inferior orbital fissure both within the temporal fossa and orbit is the key anatomical landmark.
- The temporalis muscle is reflected superiorly for subcranial pathology.
- Trismus is expected post-operatively and is prevented with jaw exercises.

The zygoma links the following regions:

- The orbit
- The temporal and infratemporal fossae

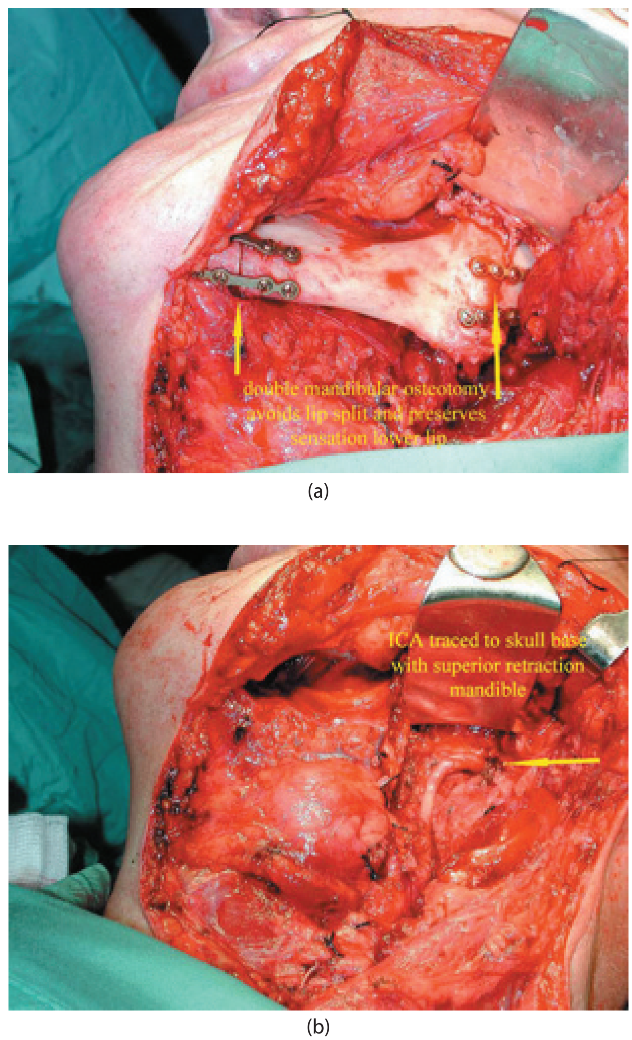


Figure 36.35 (a) Double mandibular osteotomy. (b) Superior retraction of ramus and body of mandible. (Case courtesy of Professor V. Ilankovan and Professor P. Brennan.)

Its disarticulation inferiorly pedicled to the masseter provides simultaneous exposure of the orbit, temporal fossa and superior aspect of the infratemporal fossa. A fronto-temporal craniotomy links the middle and anterior cranial fossae.

The site of the pathology determines the extent of the zygoma mobilized and whether the temporalis muscle is reflected inferiorly or superiorly.

- For subcranial lesions (orbit/temporal and infratemporal fossae) the temporalis is reflected *superiorly* after dividing the coronoid process.
- For combined exposure of the middle/anterior fossae, the orbit and/or the temporal and infratemporal fossa, the temporalis is reflected *inferiorly*.

The blood supply of the temporalis is potentially compromised with both superior and inferior reflection.

'Standard' zygomatic osteotomy

The zygomatic arch and body are exposed with a coronal flap.

When exposing the orbit as well as the temporal and infratemporal fossae, limited subperiosteal dissection is carried out *in the lateral orbit* to protect the orbital contents. The temporalis is reflected off the lateral orbit. The lateral limit of the inferior orbital fissure is identified with a blunt hook *in the temporal fossa*.
The bone cuts are as follows:

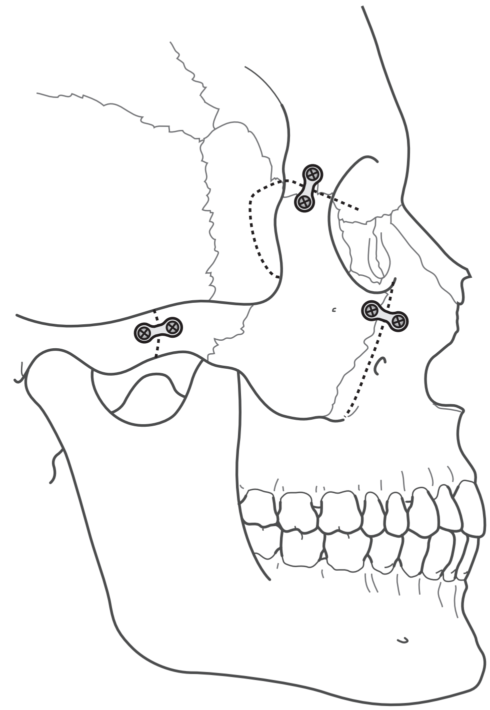
- Superiorly at the fronto-zygomatic suture.
- Through the body of the zygoma extending laterally from the inferior orbital fissure. The anterior limit of the inferior orbital fissure is first identified *in the orbit* with a blunt hook. The cut is in an inferolateral direction.
- The posterior bone cut is just anterior to the articular eminence of the TM joint.
- The bone cut in the lateral orbit extends from the superior bone cut to the lateral aspect of the inferior orbital fissure – identified earlier in the temporal fossa (Figure 36.36a and b).

If orbital exposure is unnecessary, the lateral orbital rim is left intact. A vertical bone cut through the body of the zygoma lateral to the orbital rim is made. The posterior bone cut is the same.

The zygoma is pre-localized with bone plates and screws – 1.7 mm plates are satisfactory.

With gentle taps, the osteotomy is completed with an osteotome and the zygoma displaced inferiorly. The temporalis is reflected superiorly after a coronoidectomy. The mandible is opened widely with a mouth prop increasing vertical exposure. The lingual and inferior alveolar nerves can be identified in the lateral infratemporal fossa (Figure 36.37).

For correction of a malunion of the zygoma the coronoidectomy and superior reflection of the temporalis are unnecessary.



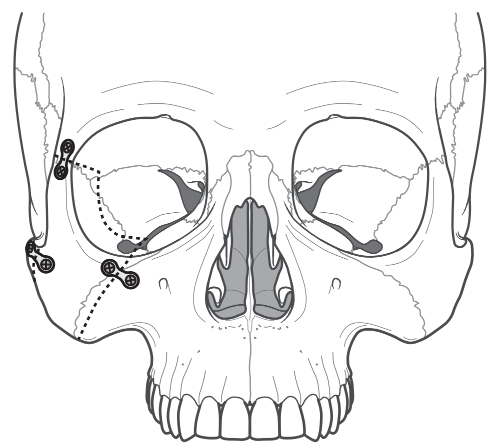


Figure 36.36 (a and b) Bone cuts for zygomatic osteotomy.

The extent of exposure of the infratemporal fossa extends:

- Inferiorly to maxillary teeth
- Medially to the lateral wall of the nasopharynx following resection of the lateral and medial pterygoid muscles

Medial exposure is restricted which limits the approach to treatment of benign pathology in the infratemporal fossa if used as the sole means of access. Malignant disease in the infratemporal fossa is better accessed with a transmandibular and/or transfacial approach.

For exposure of the lateral orbit to the apex, a fronto-temporal craniotomy is necessary. This allows the safe removal of the greater wing of the sphenoid under direct

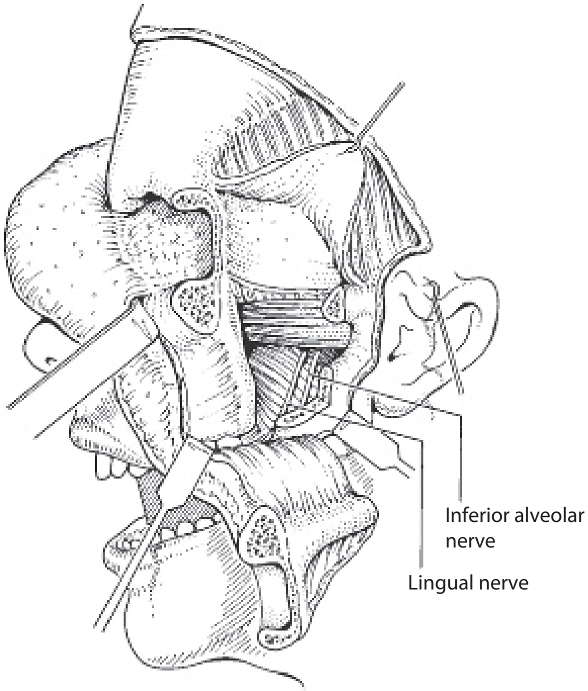


Figure 36.37 Zygoma displaced inferiorly, temporalis superiorly and the mouth opened widely. Lingual (anterior) and ID (posterior) nerves identified after resection of the coronoid.

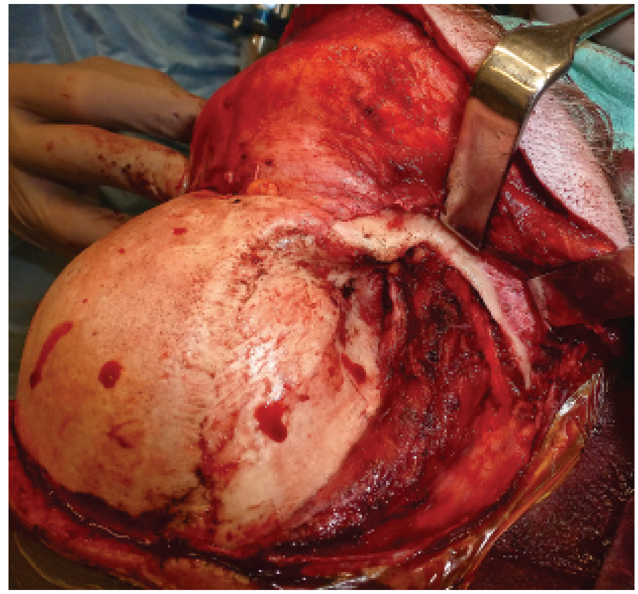


Figure 36.38 Orbital rims, temporal fossa and zygomatic complex exposed.

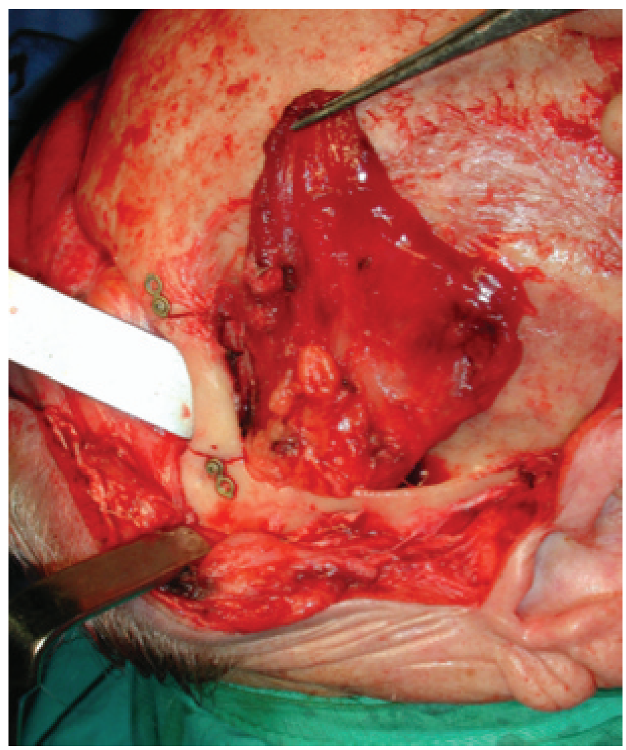


Figure 36.39 Lateral orbital rim bone cuts with pre-localized plates.

vision and the exposure of the contents of the superior orbital fissure and the optic nerve.

Lateral and superior orbitotomy

This approach is useful for lacrimal and lateral/superior/inferior extra- and intra-conal orbital lesions and for reconstruction following orbital exenteration with a temporalis flap. It can be combined with craniotomies for additional access to the orbital apex.

Surgical technique

A coronal flap is raised and the zygomatic complex exposed as described in section '"Standard" zygomatic osteotomy' for the zygomatic osteotomy. For isolated lesions, a Stallard–Wright 'S' shaped incision extending from the upper lid skin crease/eyebrow inferolaterally over the lateral orbital rim to the crow's feet skin crease can be utilized. The temporalis muscle is retracted posteriorly to expose the temporal aspect of the lateral orbit and the orbital periosteum is elevated from lateral orbital wall (Figure 36.38). The inferior orbital fissure is identified both within the orbit and temporal fossa with a blunt hook. Perforating blood vessels are identified and coagulated prior to division.

The orbital contents are protected with a malleable retractor and the bone cuts are made with a thin saw.

Superior: Just above the fronto-zygomatic suture.

Inferior: Inferior lateral orbital rim along the superior border of the zygomatic arch (the superior border of the zygomatic arch is at the same level as the orbital floor) up to the anterior limit of inferior orbital fissure (Figure 36.39).

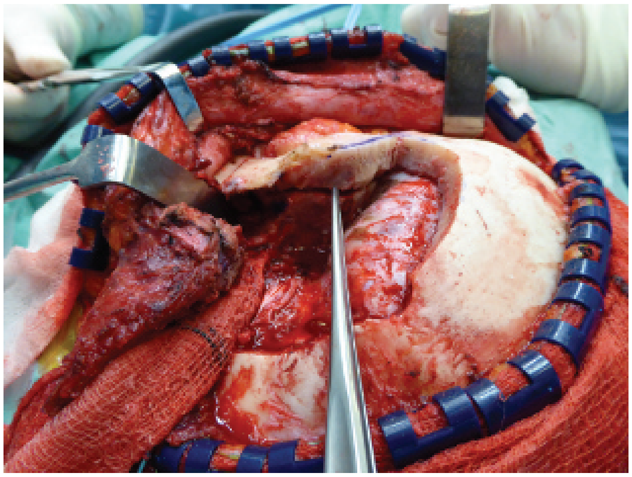
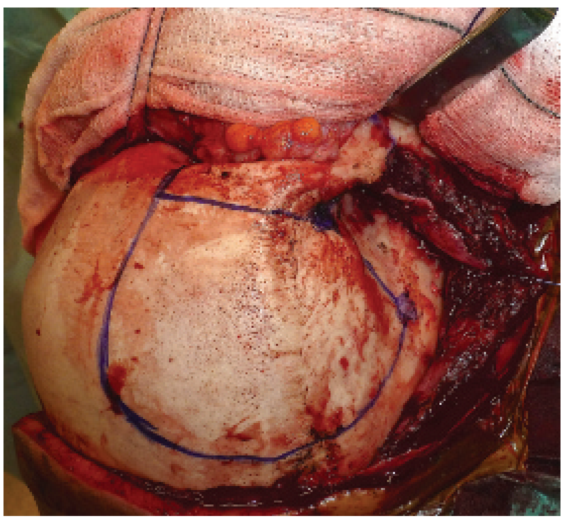


Figure 36.40 Posterior bone cut in the lateral orbital wall from the temporal aspect.

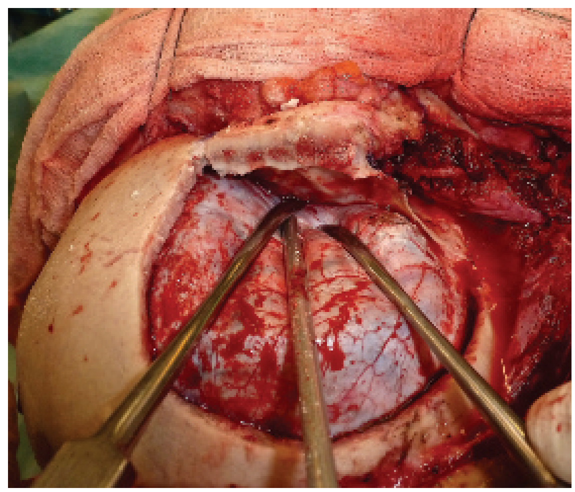
Posterior: Cut in the lateral orbital wall with a fine bur joining the superior bone cut to the anterior limit of the inferior orbital fissure (Figure 36.40). This is more easily made from the temporal aspect.

The superior and inferior bone cuts are pre-plated prior to removal of the osteotomized segment and fixed plates following completion of the procedure.

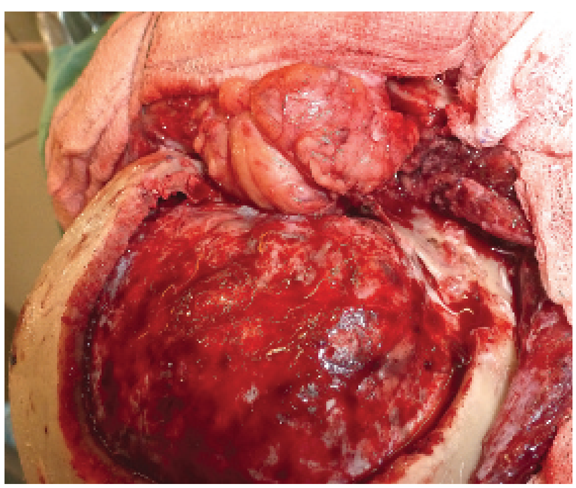
The lateral orbitotomy can be combined with a superior orbitotomy for wide exposure of the superior orbital fissure and optic nerve/canal. This is usually performed in conjunction with a fronto-temporal craniotomy. The craniotomy is best performed initially and the superior orbital wall delineated from the cranial aspect. With malleable retractors in situ, the superior and lateral orbitotomy can be carried out under direct vision (Figure 36.41a through c).



(a)



(b)



(c)

Figure 36.41 (a) Marking for superior/lateral orbitotomy and fronto-temporal craniotomy; (b) exposure of the orbital roof following craniotomy and (c) exposure following orbitotomy and craniotomy.

SUMMARY

Access	Procedure
Oral cavity	Per oral
	Soft tissue lip split
	Lip split with access mandibulotomy
	Visor flap
Maxilla	Per oral
	Modified Weber–Fergusson
	Modified Weber–Fergusson with Lynch and Dieffenbach modifications
	Lip split mandibulotomy
	Combinations
Infratemporal fossa	Modified Weber–Fergusson with Dieffenbach modification and early coronoidectomy
	Lip split mandibulotomy
	Coronal flap with zygomatic osteotomy
	Combinations
Nasal cavity	Per nasal
	Lateral rhinotomy
	Nasal osteotomy
	Sublabial/Le Fort I osteotomy
Orbit	Various soft tissue incisions
	Lateral orbitotomy
	Superior orbitotomy
	Inferior orbitotomy
	Combinations

Note: Excludes endoscopic approaches which can be utilized alone or in combinations with the open approaches.

Top tips

- The first three layers of the scalp lift as one unit in an avascular plane.
- Knowledge of surgical landmarks prevents damage to temporal branches of facial nerve.
- Closure of the galea is the most important element in wound closure.

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37

Excision of skin lesions and orbital and nasal reconstruction

BRUCE HORSWELL

CONTENTS

GENERAL PRINCIPLES

Mohs' surgery

Most facial skin cancers are basal cell carcinomas (BCCs) which are well demarcated and do not extend below the deep dermis. These lesions can be excised with a margin of 5 mm and the depth of incision is located at the level of the muscle fascia. The lesion is excised as an ellipse placed parallel to the natural expression lines (Figure 37.1), and closed without tension or distorting structures such as the eyebrow. The skin incision is made perpendicular to the surface and the wound is closed in layers. The wound edges are undermined as necessary.

Recurrent lesions, post-radiation tumours, morphoeic (sclerosing) BCC and tumours in lines of embryonic fusion require special consideration. These tumours are poorly demarcated; therefore, microscopic controlled surgery (Mohs' technique) may be required to ensure tumour extirpation. Mohs' technique is also indicated where minimal removal of normal tissue is indicated, e.g. the eyelids. The technique relies on accurate mapping of the excised specimen with microscopic examination of the deep surface to ensure complete removal of the tumour.

Figure 37.2 shows a basal carcinoma at the medial canthus (an embryonic fusion line). The excision margin is marked out as shown in Figure 37.2a (dotted line).

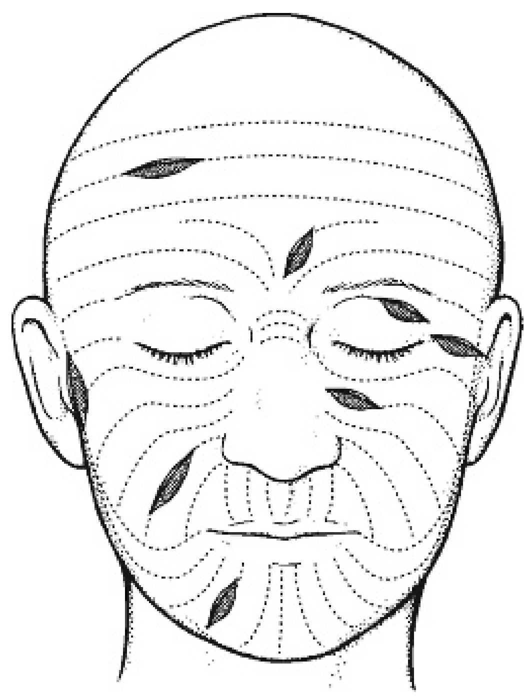


Figure 37.1 Various elliptical excisions of lesions are demonstrated. Generally, these should be placed parallel to the relaxed skin tension lines (RSTLs) to avoid tension.

The tumour is excised with the knife blade held at 45° to the surface (incision A–A' in Figure 37.2b), and a second clearance slice of tissue 1–2 mm thick is excised from the tumour bed (incision B–B'). This thin slice of tissue is turned over onto a slide with the deep surface uppermost and is divided into sections (usually four) like slices of pizza. At least one edge is stained with Indian ink or another dye to accurately orient ('map') the position of residual tumour. In Figure 37.2c, slices 1 and 4 which correspond to the nasal portion of the tumour are seen to contain residual tumour.

Further slices of tissue (5 and 6 in Figure 37.2d) will be removed in the area corresponding to specimens 1 and 4 and the process is continued until all slices are tumour free. Many Mohs' surgeons prepare frozen sections from the deep surface, and after reviewing the slides themselves continue the serial excision on the same day. An alternative method is to fix the slices of tissue for permanent section. Slides will be ready in 24–48 hours. The wound is left open and dressed with mupirocin (bactroban) cream. Further, excision is carried out in the areas indicated. An important component of this technique is review of the sections by the surgeon to ensure accurate mapping.

When the defect is tumour free, it may be closed with flaps or in some sites allowed to granulate.

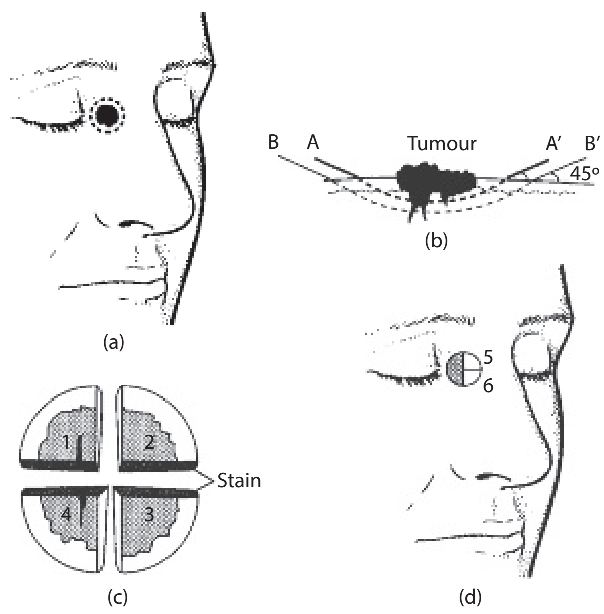


Figure 37.2 (a) Medial canthal lesion, ideal for Mohs' technique in order to preserve tissue and prevent distortion of adjacent structure after definitive repair; (b) tumour excision with blade at 45° (A–A'); (c) deep disc partitioned into four slices to be stained, analyzed and mapped to correspond to the tumour bed; residual tumour is observed in slices 1–4 and (d) residual tumour slices 1 and 4 correspond to tumour bed slices 5 and 6; in turn, these will be stained and mapped until margins are clear of tumour.

FACIAL RESECTION

Principles

Primary closure is the procedure of choice for small (<1 cm) defects where tissue laxity allows it. In the brow and temple regions, care should be exercised not to displace the hair-bearing margins. The first step in the 'reconstruction ladder' is split- or full-thickness skin graft.

For larger defects (>1 cm) or where scar contracture has altered tissue character, local flaps may be used. Local tissue flaps can be designed as V-Y advancement, rotational or transposition flaps which will be applicable at different facial sites. Where there has been loss of hair in the scalp region, a combination of staged tissue expansion with local scalp flaps can be undertaken. Temporary resurfacing of avulsion scalp wounds may be performed with free skin grafts (allografts or autografts). At a later date, tissue expansion with eventual scalp flap advancement or rotation to restore scalp integrity is performed. Total or near-total brow loss is generally reconstructed with a free tissue graft from the scalp. For smaller brow defects, punch grafts can be placed.

FOREHEAD DEFECT OPERATIONS

V-Y advancement flap

The V-Y advancement flap is used for small and moderately sized midline defects, the limiting factor being the area of tissue laxity. These flaps are particularly useful in resurfacing glabellar, nasal and medial canthal regions. The colour and texture match is excellent. The V-Y midline or glabellar flap is nourished by supratrochlear and canthal arteries and random-pattern facial artery distribution. Care must be taken to preserve the arteries, if possible, when the flap is elevated. Design of the flap (Figure 37.3) must take into consideration the pivotal point of the flap, located at the flap base opposite the defect. The inferior incision on the pivotal side should not extend below the medial canthal level in order to maintain vascularity.

The length of the vertical limbs of the flap will be dictated by the defect length and laxity of glabellar tissue.

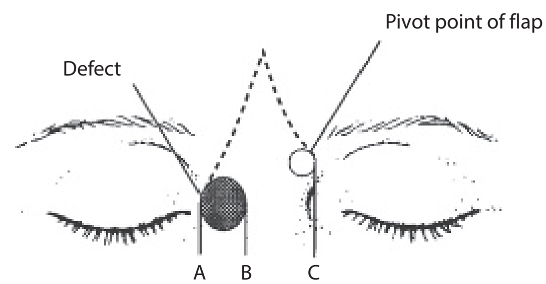


Figure 37.3 Glabellar V-Y advancement flap. Distance A–B should be no more than half of the distance A–C in order to ensure vascular integrity through the area of pivotal point C.

The base of the flap (B–C) should be half to two-thirds of the entire base (A–C) which also includes the defect (A–B). Dissection of the flap is carried out in the areolar plane to preserve subdermal plexus.

Once the flap has been elevated and turned into the defect, the flap's leading edge should be sutured to the defect margin with polydioxanone suture in a buried fashion. Closure of the V-Y segment (Figure 37.4) begins superiorly and continues inferiorly, the last sutures being placed at the pivotal area of the flap base. A standing cone (dog ear) usually occurs at the pivotal area, which may resolve over time, or require secondary z-plasties and/or dermabrasion.

Horizontal or 'H' sliding flap

With lateral forehead defects, a transposed median forehead flap (Figure 37.5) may be used; however, animation of the frontalis is adversely affected. For small forehead defects, sliding horizontal advancement flaps with incisions hidden nicely in existing frontalis relaxation lines and small Burow's triangles to facilitate closure work well. If tissue loss or resection encompasses the supraorbital nerve in its first 3–4 cm, then microneural repair should be undertaken with a cable graft using the greater auricular nerve. A vein graft or a commercially derived nerve sheath graft may also be micro-anastomosed to serve as a conduit for the regenerating nerve.

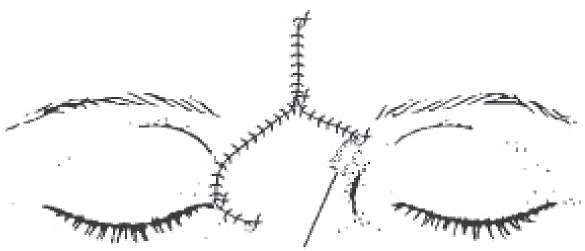


Figure 37.4 Transposition and closure of glabellar V-Y flap. The leading edge should be sutured first. The standing cone (dog ear) at the pivotal point will settle with time.

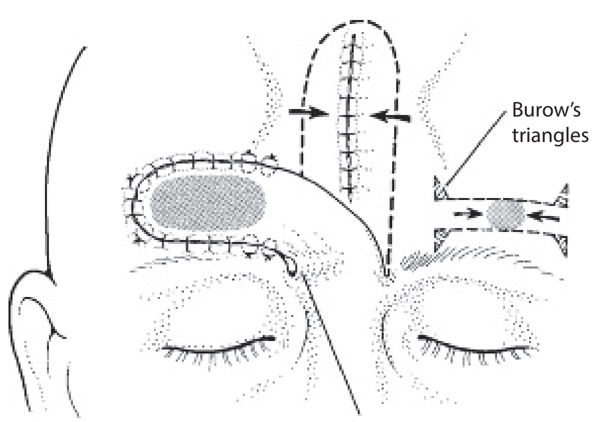


Figure 37.5 Diagram of median forehead flap to resurface a right forehead defect. Same principles apply as in a turned down forehead flap to the nasal region as described in Figure 37.3. A smaller left forehead defect is shown repaired with a sliding 'H' flap. Burow's triangles correct the standing cones at the corners.

Rotational forehead flap

Rotational forehead flaps are primarily utilized for closure of large midline defects. They have a semi-circular design with an arc of rotation near the middle of the flap. At times bilateral rotation flaps may be necessary. The midline defect is triangulated with the base at the hairline, and the apex angle may approach 50°. When the flap is designed, the leading edge should be made long enough to allow adequate rotation of the flap and coverage of the defect.

First, mark out the proposed excision and then, a triangulated defect may be constructed (Figure 37.6). If a defect is located cephalad (near the hairline), the leading edge (A–C, B–C) should be longer than the defect margin to ensure adequate rotation of the tip (A or B). In order to achieve rotation, a back-cut can be performed at the flap pedicle (D or E). Also, wide undermining of the pedicle and surrounding tissue may be undertaken; however, extensive undermining may disrupt vascular perforators.

Rotation of the flap into the defect typically leaves a secondary defect at the flap margin (BB', DD', or AA', EE').

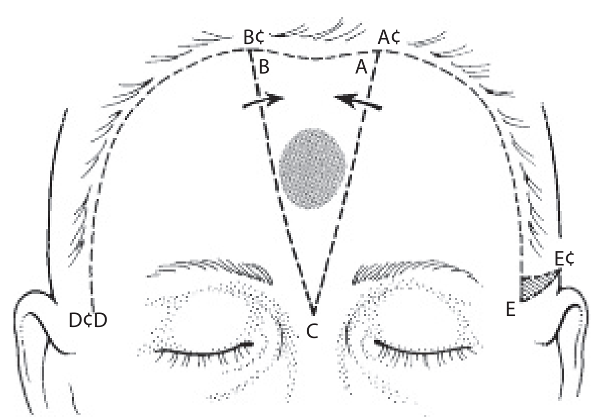


Figure 37.6 Midline defect repaired with a rotational forehead flap. The leading edges (A–C, B–C) should be longer than the defect in order to gain enough tip (points A and B) rotation. Back-cuts at the flap base (DD', EE') are necessary to gain adequate rotation. Areas of incomplete closure (AA', BB', DD', EE') will usually close with advancement of the cephalad and caudal margins.

If the defect is a narrow gap at the hairline, this can be closed by simple vertical advancement of both margins (B–B', etc.). The hairline may be temporarily displaced inferiorly in such cases. Other gaps may be closed by extending incisions to allow more rotation and distributing tension during closure along the whole of the wound margin. Rarely, free full-thickness skin grafts may need to be placed in a secondary defect caused by flap rotation.

TEMPLE AND CHEEK DEFECT OPERATIONS

Rhombic flaps

Temple and cheek area defects are closed with local tissue flaps, which offer laxity, good texture and colour matches. Transposition flaps (rhombic, Dufourmental, bilobed flaps, etc.) offer excellent repairs for small and moderately sized defects, designed and sited such that the incisions fall into relaxed skin tension lines (RSTLs) and the transposed tissue does not distort adjacent structures. There are four possible rhombic flaps for each defect; however, usually two are more favourable owing to RSTL topography. The correct donor flap extends from lax tissue and the sides of the flap, particularly the leading edge, should be slightly longer than the defect side to compensate for pivotal restraint. If the recipient skin tissue is lax, then surrounding structures, such as eyelids or eyebrow, will move towards the flap.

A rhombus is drawn around the proposed area of excision (see Figure 37.7): Two defect sides (A–B and C–D) are drawn perpendicular to the RSTLs and extended to encompass the defect. These are then connected with parallel lines and the short link diagonal (B–C) is extended to create one edge of the donor flap. As noted above, the transposed edge (B–F or C–E) and back-cuts may need to be slightly oversized to accommodate the necessary rotation and closure.

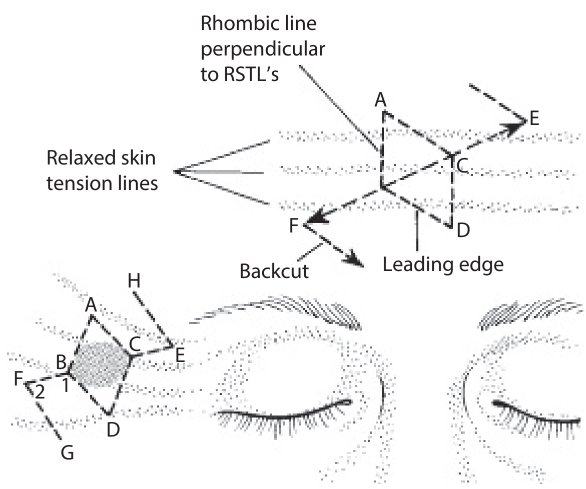


Figure 37.7 Rhombic flaps incorporate 60° and 120° angles in the design. For flap BDFG, incision F–B is equal to B–C, and F–G is parallel to B–D. The leading edge (A–C for flap ACEH, or B–D for flap BDFG) lies perpendicular to RSTLs. The more favourable rhombic flap is that which distorts surrounding tissue the least. In the temple region, this is usually the caudally based flap as shown.

Adequate recipient site and pivotal area (flap) undermining are critical for ease of transposition and minimizing tension (with consequent ischemia). Closure (Figure 37.8) begins first at the leading edge corner (1C) followed by a suture at the near corner (BG).

Several buried sutures in the deep dermis plus 'corner sutures' and mattress sutures will assist in distributing tension. The transposed flap tip (2A) should require minimal suturing, thereby reducing tissue ischemia and necrosis.

Dufourmental flap

The Dufourmental flap (Figure 37.9) is a variation of the rhombic design. Its application is in areas of limited tissue reservoir necessary for advancement or transposition of the flap. With the construction of a bisector (B–G) of the angle (EBF) created by extension of the short diagonal (A–B) and defect margin (B–C), a more obtuse leading edge margin is created. The back-cut is generally parallel to the long diagonal (C–D) of the rhomboid defect. This design diminishes the degree of vertical tension on the transposed flap.

A wider base is created in the Dufourmental design, and this may contribute to difficulty in flap transposition. However, tension at the tip is placed more lateral (not as vertical as in the rhombic design), thereby creating a more stable flap.

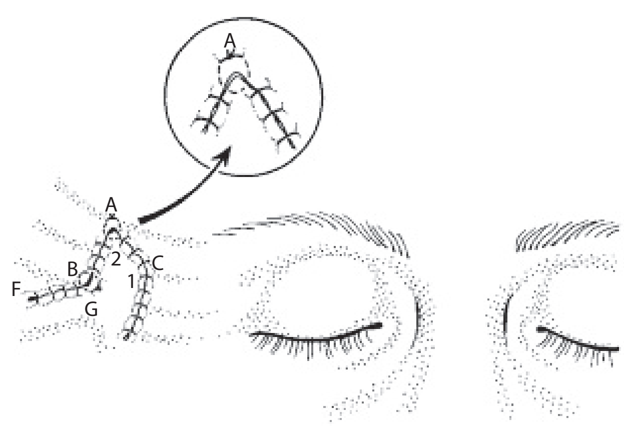


Figure 37.8 Closure of the rhombic flap begins first at 1C then corner stitches placed at the areas BG and 2A. If flap tip ischemia is evident after suturing, either too much tension exists or improper suture placement is to blame.

Bilobed flap

The bilobed flaps are a combination of transpositional and rotational flap manoeuvres. The key design involves construction of long enough limbs to accommodate the restraint at the flap base, which inevitably results from the distance necessary for transposition. A pivotal angle of >30° will usually result in 'standing cones' at the flap base. If cones persist, they may be excised secondarily.

Orientation of the bilobed flap is determined by the reservoir of tissue in the area of the defect – from the cheek area for transposition superiorly into the temple region – if the defect is high, and inferiorly as shown in Figure 37.10 if the defect is low. The incision lines should lie in relaxed skin lines.

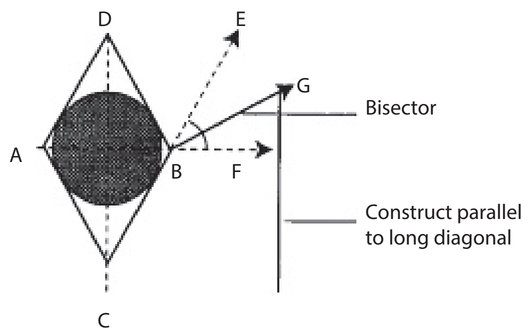


Figure 37.9 Dufourmental flap design involves constructing a bisect or incision of the angle EBF then dropping a vertical limb parallel to the long diagonal C–D.

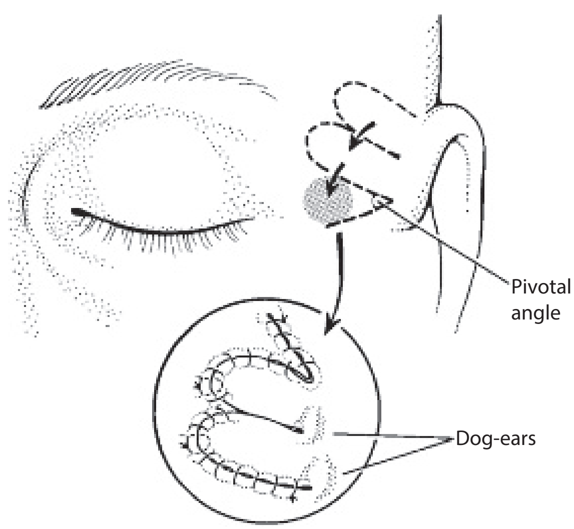


Figure 37.10 Bilobed flaps should have bases in fairly lax tissue and the incisions made parallel to RSTLs, if possible, for cosmesis and stability. Pivotal angles should be 30° or less to avoid standing cones.

ORBITAL DEFECTS AND RECONSTRUCTION

Lateral rhinotomy approach

Access to the medial orbit and ethmoid sinuses for resection of extensive tumours usually involves a combined craniofacial approach from above and access through the naso-orbital region. Craniofacial approaches are discussed elsewhere. For smaller tumours confined to the ethmoid air cells, the lateral rhinotomy approach may be used. Typically, the orbit is not entered and the eye is preserved.

The incision is carried superiorly from the alar (as in a Weber–Fergusson approach) midway between the medial canthus and mid-nasal point. Greater postero-superior access can be gained through extension of the incision into the supraorbital recess. If a margin can be safely obtained without involvement of the lacrimal crests, then the medial canthus may remain attached. Wider exposure may be obtained with canthal detachment. Osteotomizing a portion of the crestal insertion facilitates canthal re-attachment with microplate fixation. Exposure of the entire medial orbital wall is permitted. After delineation of tumour extent, a 1-cm bony margin is planned. Removal of the lamina papyracea may assist in determining tumour extent and bony margins.

To facilitate tumour exposure, the nasal bones may be osteotomized (Figure 37.11). Microplates are placed first. If encroachment on the lacrimal canaliculi or sac is anticipated, cannulation is undertaken for identification purposes and repair.

After resection, the cavity is lightly packed with gauze strips impregnated with antibiotic ointment. If resection has involved the superomedial orbital wall or cribriform plate, the defect should be lined with transposed pericranial flaps or split calvarial grafts. Such a defect may also communicate with the frontal sinus in which case a pericranial flap will serve as a barrier. Fibrin sealant is applied to secure a water-tight seal (Figure 37.12). If the

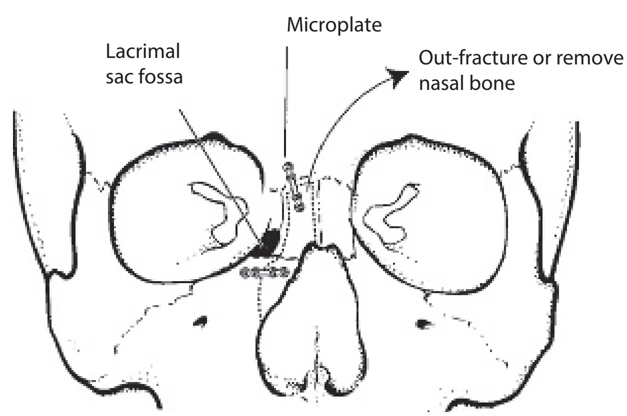


Figure 37.11 Diagram illustrates nasal osteotomy for access to the superior nasal and ethmoid regions. Fixation plates should be placed initially in situ which facilitates replacement after resection.

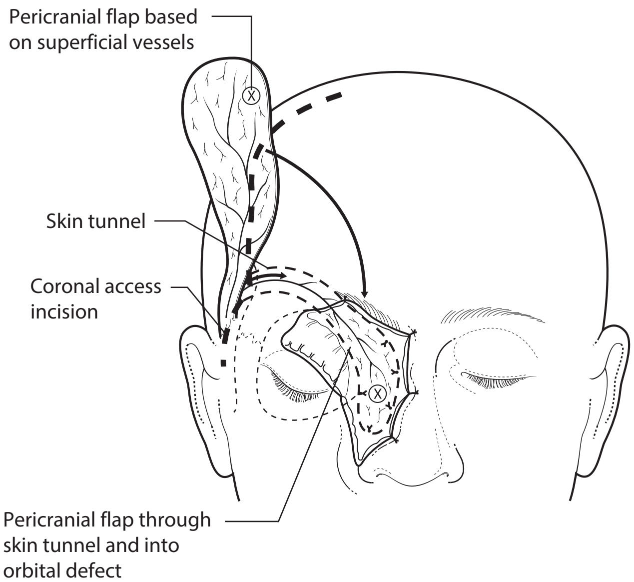


Figure 37.12 A pericranial or galeal flap may be made to cover a resection defect and provide vascularity for bone grafts. Retention of the flap to the recipient bed is facilitated by placing holes in the bony margins, suturing the flap in place, and sealing with fibrin glue. A portion of the outer calvarium may be osteotomized as a pedicled myo-osseous flap for reconstruction of the bony orbit.

frontonasal duct is implicated or frontal sinus disease is present, sinus obliteration is performed via mucosal stripping and autogenous (calvarial cortical chips and dust) bone graft placement. (Dual access for extended resection into the superior orbit or frontal sinus region is necessary via coronal and rhinotomy approaches.)

Lateral orbital masses and defects

Lateral orbital masses, usually epidermoid or dermoid cysts or tumours arising from the lacrimal gland, are approached through brow, eyelid (with or without lateral canthotomy) or coronal access incisions. Computed tomography (CT) and magnetic resonance imaging (MRI) delineate the mass size, location and vascularity. A coronal approach will allow better access for malignant lesions, particularly with skull base involvement. Transconjunctival incisions with lateral canthotomy give sufficient access for biopsy of large masses or removal of small lateral orbital tumours (Figure 37.13).

A coronal approach is performed, exposing the supraorbital and lateral orbital rims. If CT or MRI has indicated the posterior extent of the mass to be more than one-half of the orbit, fronto-orbital craniotomy is indicated. Anterior masses can be approached via an orbital rim osteotomy which is planned to allow sufficient margins of bony and peri-orbital tissue for malignant tumours of the lacrimal gland. The inferior limb of the osteotomy can be taken to the orbital floor and posterior to the sphenozygomatic suture. Before the lateral canthus is detached, it

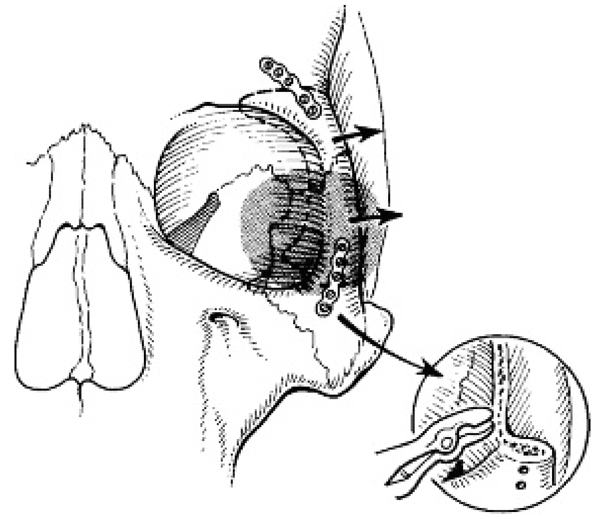


Figure 37.13 Lateral orbital osteotomies for lateral, superior or deep orbital lesions. The lateral orbital bone can be removed with rongeurs to facilitate access to the retro-orbital region.

is identified with a suture or it can be osteotomized with a small (6–8 mm) portion of lateral rim bone to allow precise reattachment with wire or micro-screw fixation. The orbital rim and wall are put aside (with miniplates attached) for later placement.

Rongeur nibbling (Figure 37.13) of the orbital wall will also create more postero-inferior access to the retro-orbital region. Superior access is best gained through a fronto-orbital craniotomy.

Combined approaches

Some posterior masses may require combined approaches to the orbit. A lateral orbitotomy (Figure 37.14a) with outward displacement of the globe combined with a medial approach will provide improved access to medial-posterior masses. An extended lateral canthotomy incision gives good exposure of the lateral rim. The anterior third of the lateral orbital wall is osteotomized and the rim is cut above and well below the frontozygomatic suture. Out-fracture (Figure 37.14b) of the lateral wall preserves the attached periosteum as a vascular pedicle.

A Lynch incision to the medial wall or lateral rhinotomy is performed. The medial canthus is identified and either tagged or osteotomized with attached bone. The medial orbital wall is removed and an ethmoidectomy performed. After detachment of the medial rectus muscle, the globe can be gently retracted laterally, thus exposing the posterior intraconal region. If access is still limited, a superior approach through the orbital roof is necessary. After tumour resection, the medial canthus is reattached with light polydiaxanone sutures or 28G wire. A gauze pack with antibiotic ointment is placed in the ethmoid resection and a small Penrose drain placed. The lateral wall and rim are affixed with miniplates.

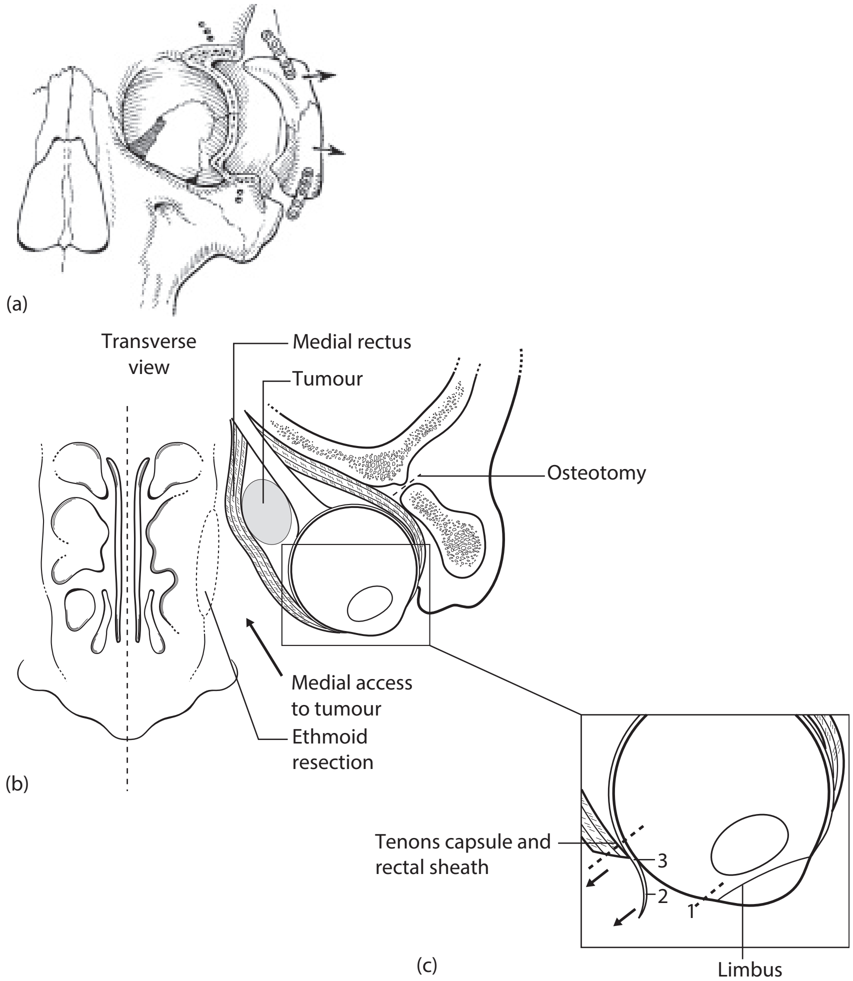


Figure 37.14 (a) Lateral orbitotomy may be performed to out-fracture the lateral orbit pedicled upon its musculoperiosteal attachment. The globe can then be mobilized laterally to provide access for medial and paranasal lesions. (b) Axial view demonstrating out-fracture of the lateral orbital wall which then provides improved medial access. (c) Enlargement demonstrating incision lateral to the limbus (1) and dissection of Tenon's capsule over the globe (2). The rectal muscle insertion (3) is incised to gain intraconal access to the lesion.

For intraconal lesions, Tenon's capsule (bulbar fascia) may need to be incised (Figure 37.14c) lateral to the limbus with dissection over the globe to the muscle insertions. Dissection here is a little more difficult and tedious; therefore, the muscle insertion is identified, incised and tagged for later reinsertion. After reflection of the muscle, dissection to the posterior intraconal region is possible.

To reconstruct lateral or inferior wall defects after orbitotomy and resection, a temporal pericranial flap may be mobilized and turned into the defect (Figure 37.12). To provide bony support for a resected orbital site, the outer table of calvarium can be harvested ('guitar pick' size), with its pericranial pedicle and tunnelled into the orbit. The subcutaneous tunnel needs to be sufficiently undermined to accommodate the flap and prevent constriction of the pericranial vessels.

Orbital floor or inferior rim reconstruction can also be accomplished by an intra-oral coronoidectomy with temporalis insertion preserved and then tunnelling the coronoid to the orbit (Figure 37.15) where it is fixed

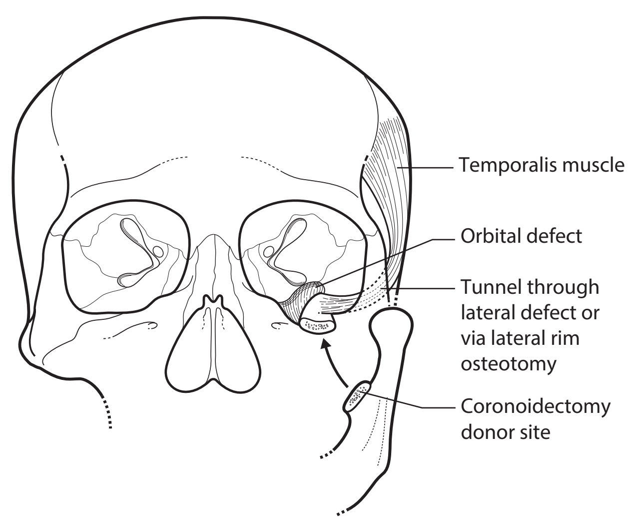


Figure 37.15 This demonstrates reconstruction of an orbital rim/floor defect with the coronoid process hinged on the temporalis muscle.

to surrounding bone with titanium miniplates. This manoeuvre will provide support to the peri-orbital tissues as well as a buttress for the lower eyelid retractors and supportive tarsal structures.

EYELID RESECTION AND RECONSTRUCTION

Principles

A variety of benign and malignant lesions are found on the eyelids. Benign lesions include nevi, keratoses, cysts (sebaceous, meibomian), papillomas, etc. Benign lesions are excised with immediate reconstruction. The commonest malignancy is BCC followed by squamous cell carcinoma, sebaceous gland carcinoma and melanoma. These lesions should be biopsied for diagnosis, then resection performed with Mohs' technique or frozen section guidance.

BCCs require a 3–4 mm margin while squamous carcinomas and melanomas should have at least 1 cm of lid margin. Deeply invading tumours affixed to bone or involving the scleral conjunctiva may necessitate exenteration. Reconstruction of the lid may involve lid remnants, local peri-orbital or opposite lid tissue, full-thickness skin grafts, local flaps, distant flaps and cartilaginous or banked tissue grafts (allografts). Eyelid reconstruction involves three types of defects: skin only, skin and orbicularis and full thickness with the tarsoconjunctival layer. Repair may also require reestablishment of the canalicular and nasolacrimal ducts. Large defects need some structural support for the reconstructed lid.

Partial defects

Partial-thickness defects are repaired by advancing local skin and muscle, or with a full-thickness skin graft. Skin grafts are harvested from the opposite lid, post-auricular region or supraclavicular area. These areas provide excellent tissue match for thickness, colour and texture. Small lid defects (<2 cm) are easily repaired with opposite lid skin, while larger areas require post-auricular or supraclavicular grafts.

The defect is measured. The donor area is 'ballooned' with local anaesthetic and a vasoconstrictor. The graft is obtained, the donor area closed primarily, and the donor skin is thinned by trimming subcutaneous tissue. The graft is fashioned to the defect, taking care to allow sufficient, loose coverage of the defect. The lid should be under full stretch to allow correct fit of the graft to the defect.

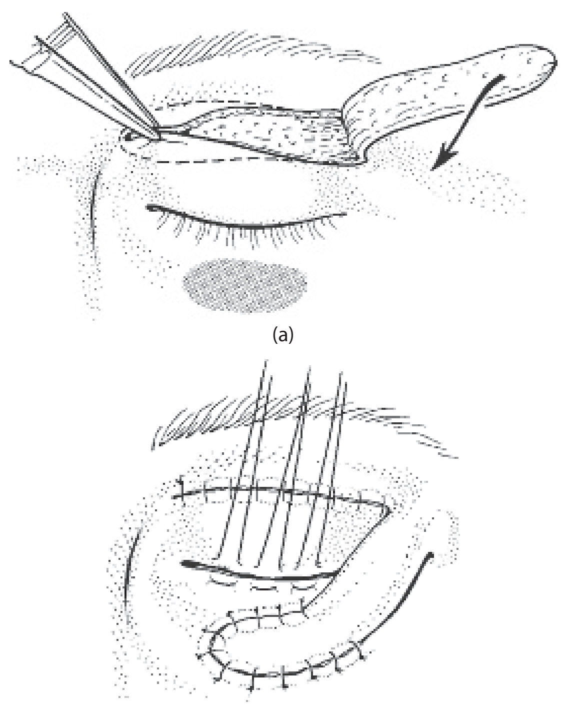
The graft is sutured in place with 6-0 black silk interrupted sutures with long tails for a tie-over bolster. For larger grafts, 6-0 chromic gut suture is placed in the mid portion to assist in graft adaptation to the recipient area. Good haemostasis of the recipient bed is critical to the success of the graft. A non-stick dressing with cotton-wool is used as a bolster. The bolster sutures are removed 7 days later.

Local skin or skin muscle advancements can also be undertaken for partial defects. A 'lid-switch' from the opposite lid (usually upper to lower lid) may be performed (Figure 37.16). The donor can be transferred as a 'bucket handle' or one end pedicled which allows more flap mobility. 'Pinching' the upper lid skin with a forceps, similar to a blepharoplasty, will assist in determining the amount of tissue available for transfer. These flaps are normally indicated for smaller, narrower defects. Both peripheral and central sutures using light chromic suture should be placed to affix the flap to the defect bed. Frost sutures should be placed for several days to reduce tension on the flap. The flap is divided 7–10 days after surgery.

Full-thickness defects

Eyelid flaps

Full-thickness defects <1 cm can usually be closed primarily by performing a wedge excision (Figure 37.17). The tarsal margins are coapted with 5-0 chromic or polyglactin suture under loop magnification in order to avoid suture placement through the conjunctiva and subsequent irritation. The lid margin is approximated by placement of a 6-0 or 7-0 silk or polypropylene suture in the lash grey-line. This suture can be left long to incorporate into the dressing at the end. Skin closure is performed with 6-0 or 7-0 interrupted nylon or polypropylene sutures. A tape dressing (Steri-Strip) is placed to support the wound. Ophthalmic



(a)

(b)

Figure 37.16 (a) Restoration of a lower lid defect may be performed with redundant upper eyelid. A 'finger flap' is created leaving one end pedicled, and then transposing to the lower defect. (b) Transposed 'lid-switch' flap is secured with interrupted suture. Frost sutures should be placed to immobilize the lid for several days. The flap is divided at 7–10 days.

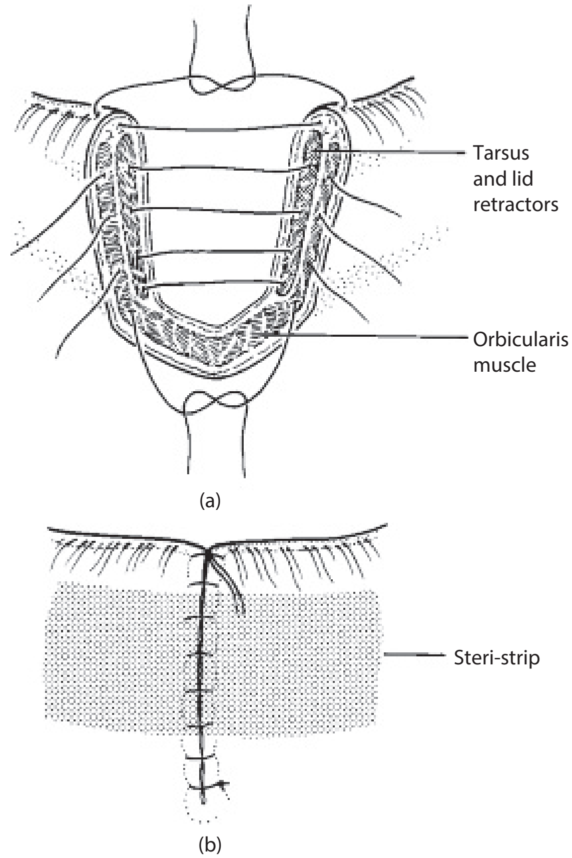


Figure 37.17 (a) Full-thickness lower lid defects <1 cm can be primarily closed with sutures placed in the tarsal plate (6-0 resorbable suture) with 6-0 or 7-0 nylon or silk at the grey line and skin. (b) The lid margin suture is left long in order to tape the tails inferiorly and avoid irritation of the eye.

antibiotic ointment is applied to the wound twice daily for 2–3 days. The lid margin stitch and tape dressing are removed at 3–4 days and the nylon sutures at 7 days.

Extended temporal flaps

Larger full-thickness defects (>2 cm) require a lateral advancement flap which is a lateral canthotomy incision which is carried laterally to the hairline, if necessary. The key to flap success is for the lateral incision to be gently curved in an upward arc for lower lid flaps, and downwards for upper lid flaps. This provides adequate vertical length to the flap as well as resistance to lagophthalmos of the reconstructed lid. Flap mobilization is carried above the musculoaponeurosis but includes the orbicularis muscle in the advanced lid to lend some support.

As the flap is mobilized and advanced medially, the conjunctiva will freely follow. A Burow's triangle is placed at the lateral-most extent of the incision to ease tension; McGregor incorporated a Z-plasty at the lateral margin. The lower limb of the 'Z' roughly parallels the defect margin. Closure begins with placement of a 4-0 or 5-0 polydioxanone suture at the canthal region to tack the lid subcutaneous tissue to the rim periosteum. The transposed Z-plasty triangles may require further mobilization and trimming to fit properly. The wound is taped for 1 week to provide flap support.

For defects too large to provide tarsus in the advanced lid, a septal or conchal cartilage support may be required. The best cartilage is harvested from the scaphoid cartilage of the ear as it usually is thin and pliable enough to prevent lid distortion.

Conjunctival coverage is provided by a turn-down flap (Figure 37.18) from the opposite lid or a free palatal or

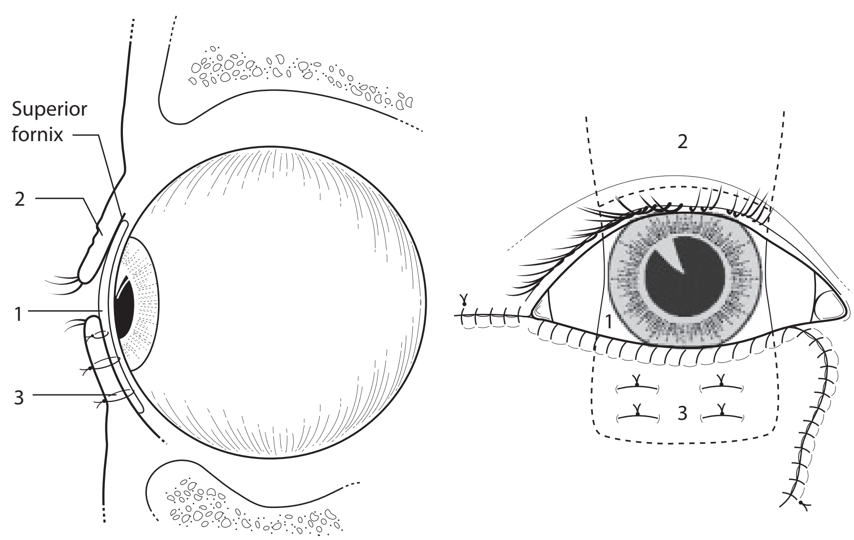
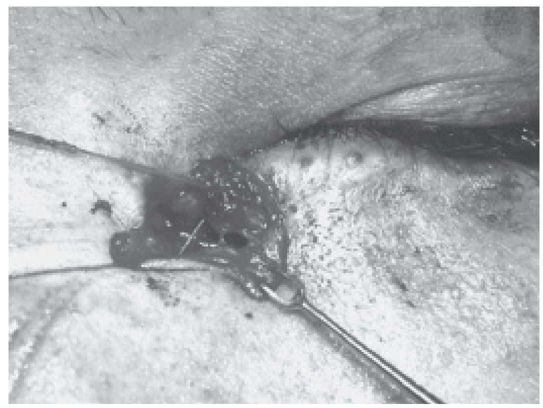


Figure 37.18 Conjunctival flap from upper eyelid to reconstruct the lower lid defect. (1) The conjunctival flap is seen lying over the cornea. (2) The extent of dissection is high into the fornix. (3) The flap is sutured into the recipient bed of the reconstructed lower lid which, in this case, is on the advanced cheek flap and secured with mattress sutures.

buccal mucosal graft. Both tissues must be secured with direct and tie-over bolsters to immobilize the flap or graft until healing has occurred. This is accomplished with fast-absorbing direct sutures as shown in the figure, making sure the knots are buried, or with full-thickness horizontal mattress sutures with or without bolsters. Frost sutures are placed to facilitate lid immobilization. The flap is divided 2–3 weeks later.

Lid defects, particularly with an element of symblepharon, may also be reconstructed with a strip of temporalis muscle and fascia with its attendant vascular supply. Figure 37.19 demonstrates clinical application of this flap. The flap is dissected on its anterior superficial temporal vessels and then tunnelled over the zygomatic arch to the orbital rim. The distal margin of temporalis is introduced via a pull-out suture into a subcutaneous pocket. The flap traverses the whole of the eyelid to its medial extent. It is secured with multiple small bolsters. Deep to the flap and superficial to the eyelid conjunctiva, a free cartilage graft should be placed to restore lid support and competency. A temporary bulge of temporalis muscle over the zygomatic arch will atrophy and flatten with time. The superoposterior 'pull' of the temporalis will naturally assist in tightening and lifting the newly reconstructed eyelid.

(a)



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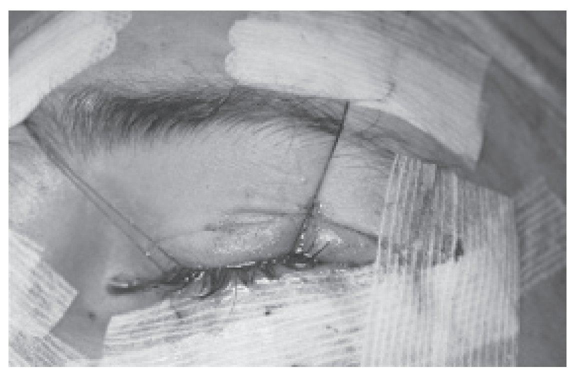


(c)

Figure 37.19 (a) Clinical photo of a temporalis myofascial sleeve for lower eyelid reconstruction. (b) Photo of temporalis sleeve introduced laterally through an extended canthotomy incision and placed in a subcutaneous pocket. Note the distal pull-out sutures which assist in flap placement. (c) Photo of reconstructed lower eyelid and post-operative Frost sutures to immobilize and support the lower lid.

Cheek flaps

Total lid defects are reconstructed with cheek rotational flaps (Figure 37.20). A lateral canthotomy approach is performed with extension to the hairline laterally and then inferiorly in the pre-auricular region. The flap is elevated above the musculoaponeurosis and carried as far medial as necessary. A small back-cut at the inferior limb will allow more superior rotation of the flap. A chondral–perichondral graft is placed and sutured into the defect with buried 5-0 chromic gut suture. A pull-out light nylon suture may also be placed to assist in stabilizing the cartilage graft. These flaps have a tendency to migrate inferiorly after healing, resulting in some element of cicatricial ectropion and dystopia. If the malar fat pad is present, then superior 'lifting' of the pad with 2-0 clear nylon or polydioxanone sutures pexed to the lateral rim periosteum will help to resist inferior gravitational pull of the cheek flap. Conjunctival reconstruction is undertaken as previously described. Care must be exercised to avoid sutures piercing the remnant of conjunctiva which will result in abrasion and irritation. Tape dressing is placed for 1 week and ophthalmic antibiotic ointment applied for 3 days.

NASAL DEFECTS

Nasal skin is thick, sebaceous and relatively inelastic which makes reconstruction with nasal tissue challenging. In nasal reconstruction, the surgeon should approach the nasal subunits separately – the dorsum, tip and alar regions. Each has its own characteristics which define repair. The nasal area has a blood supply from two sources; a rich terminal network of the facial artery which spreads onto the nose as angular and alar branches. These anastomose superiorly on the dorsum with terminals of the ophthalmic artery – the medial palpebral and dorsal nasal.

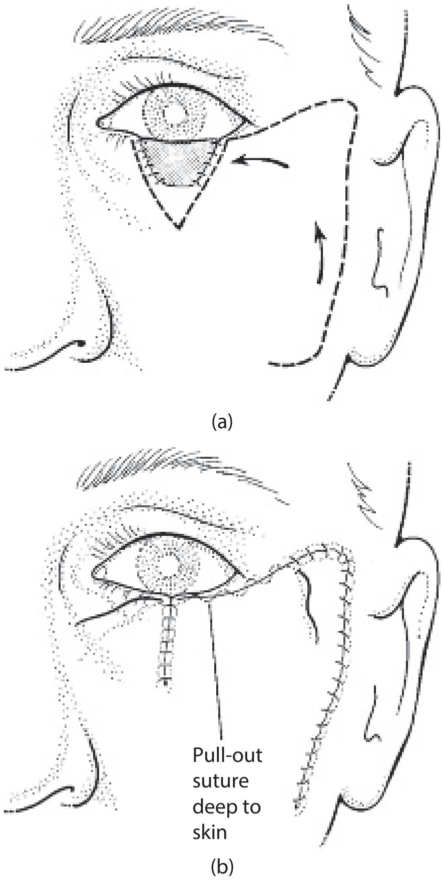


Figure 37.20 (a) Large lid defect is reconstructed with a cheek advancement flap as outlined. A free chondral–perichondral graft harvested from the ear is placed and secured to the conjunctival margins with buried 5-0 or 6-0 chromic suture. (b) Closure of cheek advancement flap. Eyelid margins are closed with a running or subcutaneous 6-0 nylon suture.

Usually flaps from the glabella and radix can be planned based upon these latter two vessels.

Nasal dorsum defects

Defects of the dorsum may be resurfaced with either a glabellar flap (superior defects) or dorsal nasal flap (inferior defects). The glabella flap (Figure 37.21) may be modified to cover defects up to half of the upper dorsum of the nose. The limiting factor in flap transposition is the pivotal area where the nutrient supratrochlear vessel enters the flap. Suturing is in two layers with buried 4-0 polyglactin suture subcutaneously and 5-0 or 6-0 nylon for skin. The leading edge of the flap is under the most tension; therefore, vertical mattress sutures may be helpful in maintaining flap position and viability.

The dorsal nasal flap is pedicled on the medial palpebral vessel. As long as this artery is preserved, a large flap can be raised off the upper dorsal surface and extended into the glabellar region. The flap rotates around the pedicle and so kinking of the vessel must be prevented. Also, a dog ear remains at this pivotal region but should be corrected secondarily.

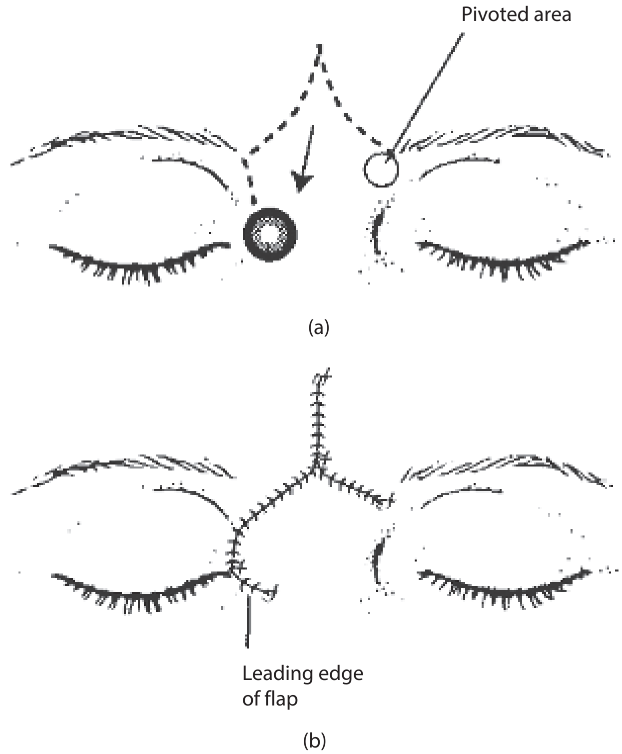


Figure 37.21 (a and b) Diagram of glabellar flap to cover a small nasal dorsal defect. The pivotal area includes the nutrient vessel (supratrochlear).

Large nasal defects

The paramedian or midline forehead flap is used for resurfacing large nasal dorsal and tip defects. This is a staged procedure, the first stage for placing the flap and a second stage 2–3 weeks later to divide the pedicle. The flap offers a fair tissue match for the nose, particularly in thicker skinned individuals.

Vascularity to the flap is via the supratrochlear vessels (Figure 37.22), which allows the total vertical dimension of the forehead to be incorporated in the flap. The contralateral vessel is selected as the pivot point for the flap base to prevent kinking of the vessels with subsequent failure and necrosis.

Two vertical limbs extending from the nasal root area are inscribed, and these may taper to the hairline or run parallel to be joined by a horizontal limb at the hairline. Doppler flow can be used to confirm supratrochlear artery location. Prior to the incision, the precise defect size and shape should be traced as a template and transferred to the donor site. Verification of flap length is confirmed with a gauze strip extending from the pivotal base to the donor site plus about 10% extra to allow for adequate tissue when

turning the flap inferiorly. The incision is carried down to periosteum and a subgaleal dissection performed. Periodic Doppler assessment will confirm vessel viability. If tissue blanching disappears, this is usually due to vasospasm which will resolve after several minutes.

The flap is trimmed to fit the recipient site and sutured in place with polyglactin suture in the deep dermis and fine suture for the skin. A drain or gauze wick may be placed under the tissue bridge.

The donor site is closed (Figure 37.23) by first widely undermining the forehead tissue with fine, vertical galeal incisions to gain laxity. Next, heavy (2-0 or 3-0) sutures are placed in the galea to gain tissue approximation. Periodic vertical mattress sutures can be placed for skin approximation in conjunction with a running suture.

The flap is divided 2–3 weeks later. Usually the flap base can be discarded; however, if the brows have been displaced too far medially, then return of the flap base in the glabella region will correct it. Persistent lymphedema often accompanies these flaps for several months and manual massage may be helpful in resolving edema of the reconstructed nasal tip.

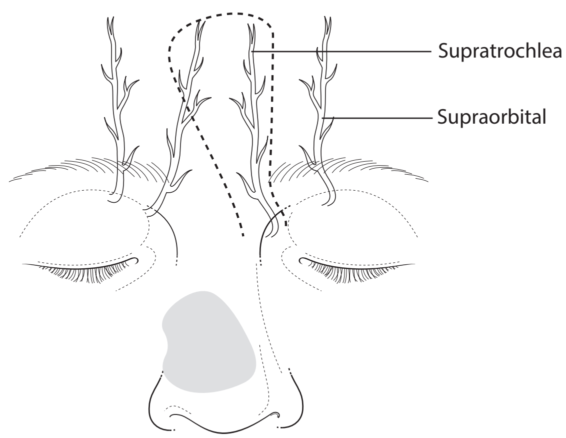


Figure 37.22 Diagram illustrating pattern of vascular supply to the forehead region. The contralateral vessel is selected as the nutrient pedicle to the flap.

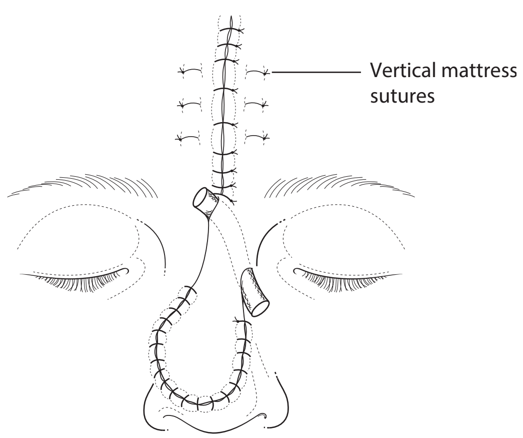


Figure 37.23 Closure of defect and donor site. A gauze wick should be placed under the bridge of tissue to maintain hygiene until the undersurface sufficiently heals.

Nasal tip defects

Nasal tip lesions usually require full-thickness skin excision and if there is tumour extension to the deep dermis, cartilage should also be included in the resection. Full-thickness skin defects of the nasal tip can be resurfaced with local nasal flaps or nasolabial flaps. Local flaps are optimal for tissue colour, texture and thickness match.

Lobed flaps are popular for small nasal tip defects off the midline. After excision, a decision must be made whether a one- or two-lobed flap is required. Generally, the larger the defect and the closer to the midline, the more lobes are required (Figure 37.24). Lobes derived from the nasal side wall do not transpose easily but those from the nasolabial area are more mobile and therefore they can be narrower as the donor sites are easily closed.

Tip defects just off the midline may result in some distortion when resurfaced from lobes nearby. The alar rim is particularly affected; however, this usually settles with time. The leading edge is under the most tension so a two-layered closure with an occasional vertical mattress suture is done.

Larger central tip defects are best restored with tissue transposed from a more distant flap, such as the dorsal nasal flap or forehead finger flap as previously discussed (Figure 37.25). The nasolabial flap can also be used if thickness and colour are similar. Persistent tip lymphedema will be most pronounced and enduring, and ultimate nasal tip form will not be attained until at least 1-year post-operatively.

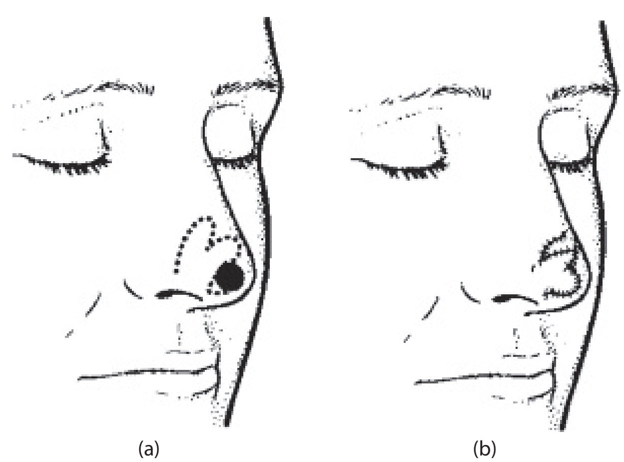


Figure 37.24 (a and b) Nasal alar or domal defects may be restored with a transposed bilobed flap. These local flaps offer good texture and colour matches. More lobes are created for larger defects closer to the nasal midline.

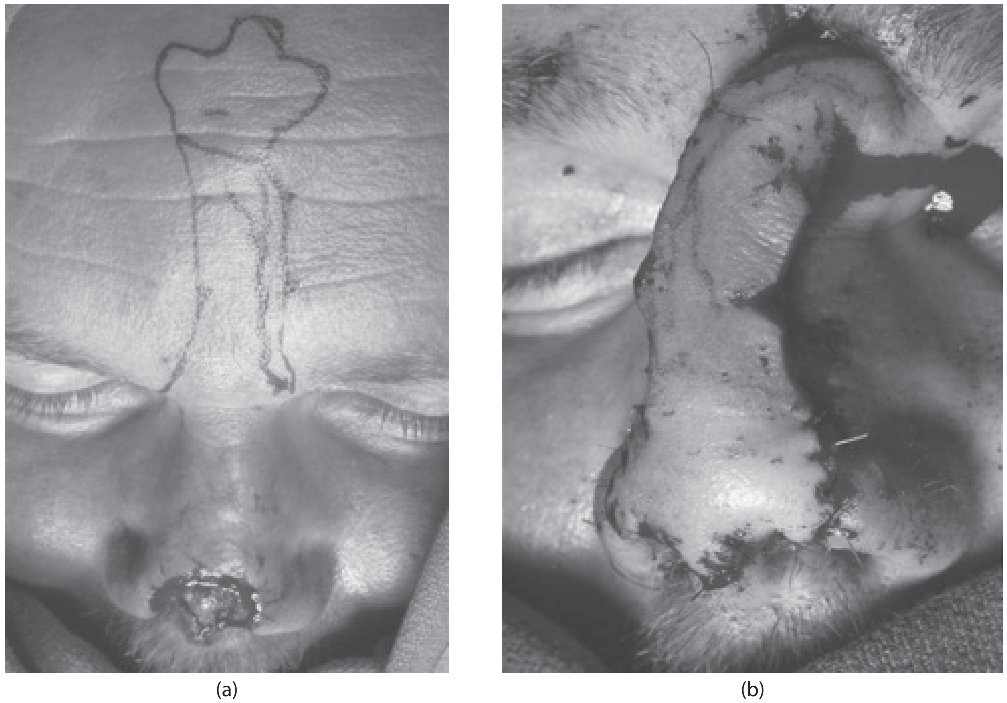


Figure 37.25 Clinical photos demonstrating application of the forehead flap for reconstruction of a nasal tip defect. (a) The flap is marked after confirmation of the supratrochlear vessel and the defect size and length of flap is verified. (b) The flap is sutured into place with buried 4-0 or 5-0 resorbable sutures and 5-0 nylon sutures. A gauze wick dressing is placed under the tissue bridge.

Alar rim defects

Lesions of the nasal ala usually require excision that includes cartilage or results in total rim resection. Restoration of the alar contour requires enough tissue to fold over, e.g. a nasolabial flap, or a free composite graft from the ear.

Nasolabial flaps can be pedicled superiorly, rotated medially and turned in on itself to restore rim contour and bulk (Figure 37.26). The distal portion of the flap is at risk for ischemia because kinking of the small vessels typically occurs at the fold area. Suturing should be enough to hold the flap in place as there is little tension on the flap. Division of the pedicle is then carried out in 2–3 weeks.

Alar rim defects up to 1.5 cm can be repaired with auricular free grafts of cartilage or composite grafts of skin and cartilage (Figure 37.27a). The outer helix provides an acceptable contour and bulk for restoration of the rim. Since these are free grafts, it is important to stabilize the graft in order to allow capillary ingrowth and tissue survival. The size and depth of the defect dictates what portion of the helix provides an appropriate match. The outer helix is good for long but shallow defects where a rigid span is required, however, the fleshier lower helix or that portion next to the superior crus provides more bulk and depth when required. The longer the graft the greater the risk of necrosis.

A template of the rim defect is taken to the helix and drawn carefully in place. 'Foot extensions' should be incorporated in the graft. These will insert into medial and lateral pockets in the defect. Prior to graft placement, soft tissue pockets are created in each defect margin where the cartilage feet will be inserted and sutured to remnant rim cartilage and tissue. One 3-0 nylon suture is placed through each defect from out to in, piercing each 'foot' (Figure 37.27b). This is then brought back up through the graft and nasal skin from the inside. Antibiotic gauze

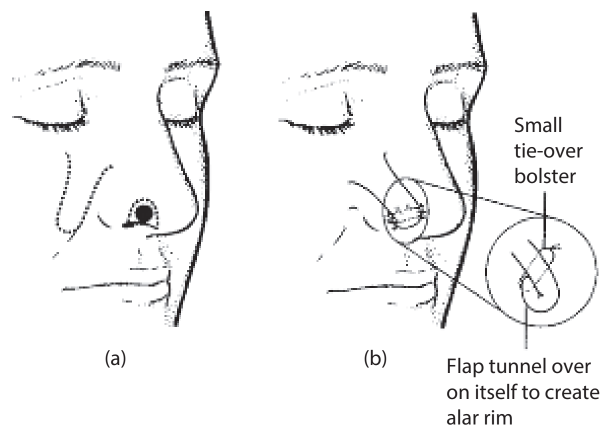


Figure 37.26 (a and b) Alar rim defect is restored with a local nasolabial flap. The flap may be turned over onto itself to restore the rim margin with lined tissue. A through and through tie-over bolster is then applied to provide form and stability of the flap.

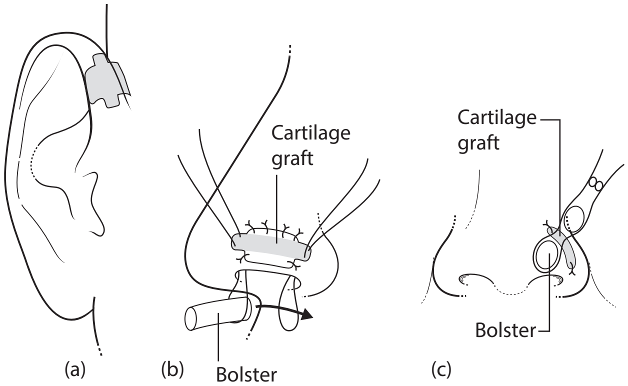


Figure 37.27 (a) Composite skin-cartilage free graft from the outer helix is demonstrated. Extended cartilaginous 'feet' are harvested to insert on either side of the defect and provide additional support and form to the rim. The donor site is closed primarily. (b) Retention of the free graft is obtained with through and through sutures to secure the graft. (c) Intra- and extra-nasal bolsters are placed through the sutures to assist in flap stabilization.

Figure 37.28 (a) Clinical photos of a post-ablative defect of the right ala with complete nasal stenosis. (b) Two-week post-op after composite auricular graft placed. Note the regrowth of skin and nasal aperture restoration.

pledgets 3–4 mm in diameter are placed intra- and extra-nasally through each nylon suture loop to serve as a bolster for the graft (Figure 37.27c); 4-0 and 5-0 nylon is placed to secure the remainder of the graft to its recipient site. The graft typically appears dusky for the first 48 hours after which vascular ingrowth will be evident. If hyperbaric oxygen is available, this has served well in 'resurrecting' or enhancing the 'take' of large free composite grafts. The bolster and sutures are removed after a week and the graft stabilized with tape dressings for another week. Some free grafts lose their pigmentation or do not have as much vascularity as surrounding tissue so that they are readily noticeable. Cosmetic tattooing can be done if the colour match is not acceptable. Figure 37.28 demonstrates a composite auricular graft to a post-ablative defect of the alar rim and complete nasal stenosis.

Total nasal defects

Total nasal reconstructions are performed in several stages. The first stage is providing adequate soft tissue coverage, both extra-nasally through the forehead flap and intra-nasally with local mucosal flaps. Free mucosal flaps harvested from the buccal mucosa may be necessary to provide a physiologic intra-nasal covering and prevent cicatrization of the raw flap undersurface. Intra-nasal stents and bolsters are necessary to maintain nasal patency and function.

Once adequate soft tissue is in place, cartilaginous struts and framework harvested from the nasal septum, conchal bowl, and crestal regions can be undertaken. Overgrafting is usually necessary as cicatrization and retraction generally ensue over the next several months after graft placement.

Final stage reconstruction involves soft tissue adjustments to the nasal base (dermabrasion or excision of scar), tip (thinning thickened transplanted forehead skin) and alar rim areas (selective thinning of cartilage or skin). Great care should be exercised to avoid compromise of the lining mucosa and nasal vestibular area.

Scalp reconstruction

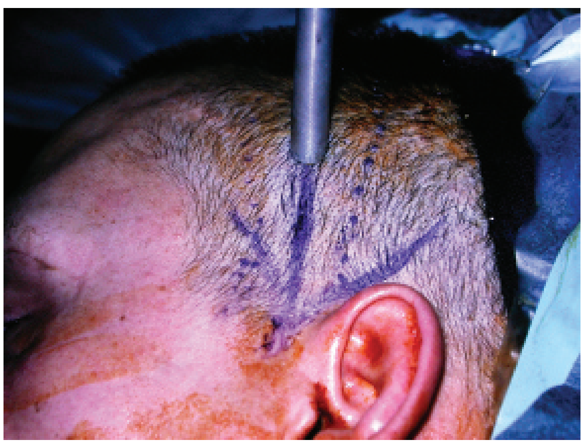
Planning for scalp reconstruction must consider the size and location of the defect, tissue reservoir, health of the recipient defect and contiguous tissue and systemic or psychological issues which may impact upon the proposed treatment. The underlying connective tissue of the scalp does not allow sufficient laxity for simple direct wound closure. Small defects (<2–3 cm^2) can usually be closed with local rotational or advancement flaps. Generally, the length of a scalp flap should be four to six times the diameter of the defect site if primary closure is planned. This amount of scalp mobilization often mitigates against its use for large defects. Defects that are greater than 3 cm^2 will require large field rotational flaps or tissue expansion in order to mobilize and move enough desirable tissue into the recipient site.

A variety of rotational flaps incorporating crescent-shaped or 'pinwheel' designs can be utilized for small avulsion defects. The temporal myofascial flap is a smaller but reliable flap for small- or medium-sized defects where calvarial coverage is desirable prior to a free skin graft. These flaps are based on the superficial temporal vessels which will allow rotation forward to the orbit or posterior to the post-auricular region (Figure 37.29). The vessels should be mapped out with a Doppler to confirm location and integrity.

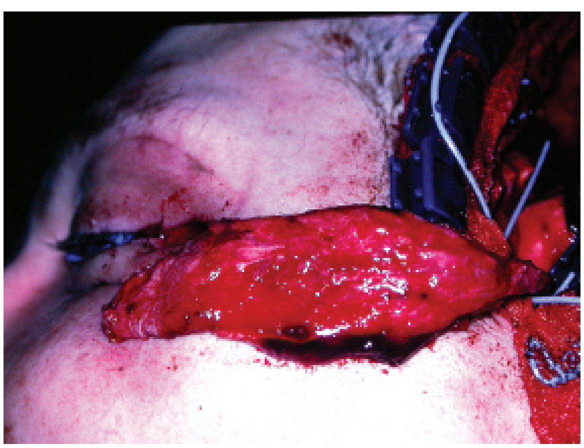
Larger defects of the hair-bearing scalp are best covered with similar tissue of texture and composition, therefore tissue expansion is preferred. True scalp expansion can be achieved through mechanical creep (skin expansion beyond its natural laxity) and biologic creep (cellular response to tension). Site preparation may involve serial wound debridement, pressure-vacuum devices to encourage neovascularization and granulation, and maturation of the recipient site prior to reconstruction or tissue expansion (Figure 37.30).

Expander selection is based on the size and location of the defect. Oval and rectangular expanders work well on the frontal and forehead regions, whereas crescent-shaped expanders work well on the parieto-temporal and occipital regions. The size (volume) should be approximately 2–2.5 times the volume (surface area) of the defect. Typically, 200–250-mL crescent-shaped reservoirs (Figure 37.31) have been the workhorse expanders in the author's practice.

The depot site is placed within the defect region of scalp for similar texture and composition but not contiguous in order to avoid defect expansion, dehiscence and exposure of the reservoir. The incision for placement can be located



(a)



(b)

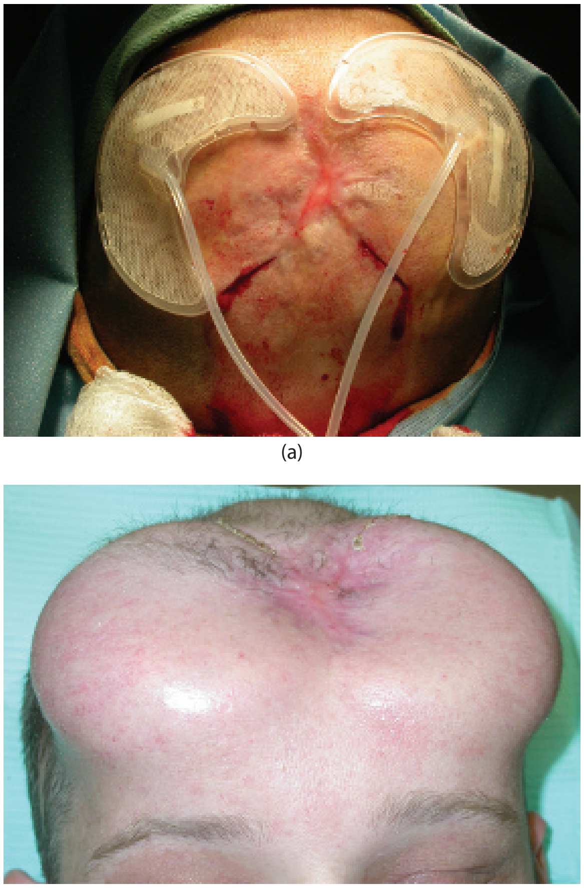
Figure 37.29 (a) Doppler confirmation of the superficial temporal artery. (b) Temporalis myofascial flap for peri-orbital reconstruction.

(a)

(b)

(c)

Figure 37.30 Serial photos of scalp defect preparation after traumatic avulsion. (a) Avulsive injury with necrotic tissue and exposed calvarium. (b) Pressure-vacuum device after initial debridement. (c) Defect bed preparation with early calvarial granulation.



(a)

(b)

Figure 37.31 Tissue expansion. (a) Forehead-vertex reconstruction with crescent-shaped expanders. (b) Mid-expansion of scalp reservoir tissue.

at the margin of planned excision or in the advanced margin of scar where future excision and closure will take place (Figure 37.32). However, care needs to be exercised in order to avoid dehiscence of the incision once expansion is underway; therefore allowing the tissue to settle (about 2 weeks) and permanent suture closure of the access site are recommended before expansion is commenced.

Port placement can be either buried (acceptable for adults) or externalized through a small stab incision for easy and painless access to the diaphragm of the port (good for children). Expansion is performed on the table to confirm proper placement and orientation, removal of dead space, and to begin initial expansion. Blanching of the overlying tense skin should be observed, then resolve in a few minutes after initial vasoconstriction. If not, then removal of some saline is in order. Expansion then takes place about every 2 weeks with instillation of 20–30 mL of saline or until the skin blanches. Confirmation of return of skin vascularity is paramount after each expansion session and documented.

Expansion can generally be performed with an oral sedative for children and pre-expansion acetaminophen or ibuprofen. Adults tolerate expansion quite well. Patient cooperation for timely visits and excellent hygiene are paramount in success of the planned expansion. Figure 37.33

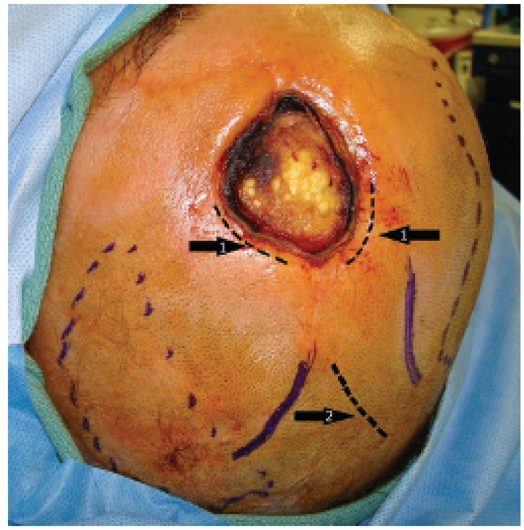


Figure 37.32 Photo demonstrating planned expander placement for a central scalp defect and access incisions. (1) Incisions at the defect margin where lateral tunnelling can be made to each site. (2) Mid-site incision distant from the defect for access to both sites.

(a)

(b)

Figure 37.33 Tissue expansion for temporal alopecia in a 5-year old. (a) Pre-expansion. (b) Six-month post-expansion with good temporal coverage of hair-bearing scalp.

Figure 37.34 Extrusion of the expander through compromised skin and the access incision site which was placed too close to the reservoir.

illustrates reconstruction of temporal alopecia in a 5-year old who successfully underwent tissue expansion.

Complications include expander dehiscence either into the access site or depot site (Figure 37.34) and infection, which is uncommon. Dehiscence and exposure of the reservoir will delay treatment unless expansion is near the end at which time the expander can be removed and reconstruction may proceed. Usually dehiscence of overlying skin suggests either overinflation, insufficient time between expansion periods, poor overlying tissue and/or patient systemic factors, e.g. smoking or diabetes.

Top tips

Flap design in the facial region should consider the following essentials:

- Optimum colour, texture and skin appendage match.
- Minimal distortion of donor or recipient site landmarks (e.g. brow, lid, lips, nasal ala) after reconstruction.
- Plan for flaps with minimal tension.

Posterior orbital tumours can be accessed through the following:

- Lateral rhinotomy with medial canthotomy.
- Lateral orbitotomy and orbital wall resection.
- Dissection of Tenon's capsule and disinsertion of the rectus muscle for intraconal lesions.
- Fronto-orbital osteotomy (craniofacial approach) for postero-superior masses.

Eyelid reconstruction must address the following:

- Skin coverage of good match from upper or contralateral lid or post-auricular skin.
- Adequate length, laxity and support of flaps to avoid post-operative cicatrization and lid incompetency in conjunction with judicial use of cartilaginous grafts and tarsal fixation techniques.
- Sufficient inner (conjunctival) lining to provide a physiologic covering for the globe.

Nasal reconstruction of the dorsum and tip is optimally accomplished through the following:

- Forehead (paramedian) flaps.
- Deferred correction of standing cones ('dog ears') – these often settle with time.
- Inform the patient of prolonged tip lymphedema.

Optimal scalp reconstruction depends on the following:

- Proper wound bed preparation to receive local flaps or expanded tissue.
- Mobilizing similar tissue from a depot of scalp in the same regional subunit.
- Patient selection and preparation for tissue expansion for compliance, emotional and psychological suitability, and timing issues.

All properly selected and placed flaps will improve in appearance with simple massage, skin support dressings (silastic), and *time* – the patient must be informed of this beforehand.

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38

Local resection and reconstruction of oral carcinomas and lip cancer

ROBERT A ORD and DONITA DYALRAM

CONTENTS

PRINCIPLES AND JUSTIFICATION

The standard of care for most lip and oral cavity cancers still remains today as primarily surgery. Although radiation therapy may be equally effective in T1 and T2 cancers, it is reserved for the patients who are medically unfit, refuse surgery or have unresectable disease. The major guiding principle of surgery is excision of the entire cancer with negative margins. Negative margins are usually regarded as 5 mm or more histologically normal tissue around the squamous cell carcinoma. To achieve this, surgeons usually makes their incision >1 cm around the palpable defined margins of the cancer.

INDICATIONS

Any surgically resectable tumour of the lip or oral cavity is an indication for a wide-local resection. The resection of the lip and oral cavity may be combined with a neck dissection depending on the depth of invasion and the TNM stage of the cancer. The need for adjuvant radiotherapy and chemotherapy depends on specific criteria outlined by the relevant national guidelines.

PRE-OPERATIVE

Anaesthesia

These operations are generally undertaken in the operating room under general anaesthesia administered through a nasal endotracheal tube. The need for a tracheostomy is dependent on the size and location of the cancer and the planned method of reconstruction. Some surgeons perform a pan-endoscopy in patients who are smokers and drinkers prior to commencement of the ablation of the tumour.

OPERATION

Carcinoma of the lower lip

Resection of the lip and repair can be divided into lesions requiring one-third of the lip or less to be resected, one-third to two-third of the lip to be resected and those tumours needing more than two-thirds of the lip resected.

Tumour requiring less than one-third of the lip resection

In lesions involving less than one-third of the lip the natural elasticity of the lip will allow primary closure. For small lesions, a shield-shaped incision gives the greatest diameter at the vermilion border and avoids the flattening of the lip often seen with simple 'V' excision (Figure 38.1). Some surgeons prefer to use methylene blue as a temporary tattoo to assist with accurately repositioning the skin vermilion interface during closure.

The lip is held tightly compressed between finger and thumb by the assistant who also assists with everting the lip. The initial incision through skin is made with a no. 15 scalpel blade; the excision is continued with either a scalpel or a needle-tip electrocautery through the orbicularis oris. The labial artery is encountered superiorly under the mucosal surface. The artery can be clipped, ligated or cauterized and excision can be completed. Once the tumour is excised, frozen sections can be taken at the vermilion margins.

The lip can then be closed using a combination of chromic gut, vicryl and sutures. The skin vermilion border is sutured first. The orbicularis oris muscle is re-approximated with vicryl and then the mucosa and skin is closed.

For a slightly larger lesion, a 'W' incision is planned (Figure 38.2). Here a 3–5-mm margin is outlined with a marking pen to provide an oncologically sound resection. The resection is similar as outlined above and the 'W' incision is closed as a 'Y'.

Vermilion

Actinic damage may affect the entire lip. For those patients with actinic keratosis or multifocal dysplasia and superficially invasive carcinoma vermilionectomy is warranted. This procedure can be undertaken by two methods: CO_2 laser or scalpel. The entire vermilion from the wet line to the skin is marked out with a marking pen. If the surgeon prefers to use the laser, it is calibrated and the mucosa is ablated with two to three passes. Each pass is completed in a different direction. If the preferred method is surgical, once the site has been marked, the lower lip is stretched by using skin hooks placed in the commissure. A no. 11 blade is then used to transfix the width of the vermilion starting at one corner. With a sawing motion, the blade is advanced to the opposite commissure. This technique can be combined with any of the lip resection outlined in Figure 38.3a and b. The depth of tissue removed will depend on the depth of the lesion and can reach up to 3 mm. The closure of the vermilion when using the scalpel is by local advancement of the mucosa. However, this causes thinning of the lip and eversion of any beard bristles. In the case of the laser, the area can be left to granulate. If more substance is needed for the lip, a tongue flap can be used to add bulk. A bucket handle, which is 5 mm thick, is created on the dorsum of the tongue and advanced to the lip (Figure 38.4). The dorsum of the tongue is closed primarily and the bucket handle is sutured to the lip. This remains attached until it is

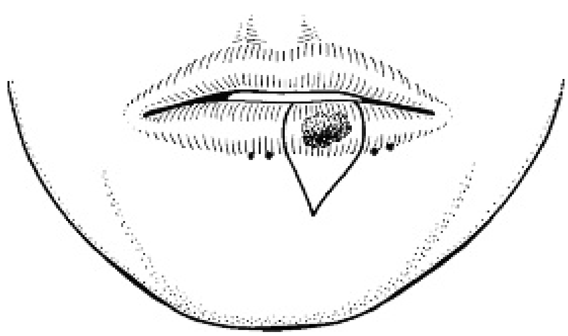
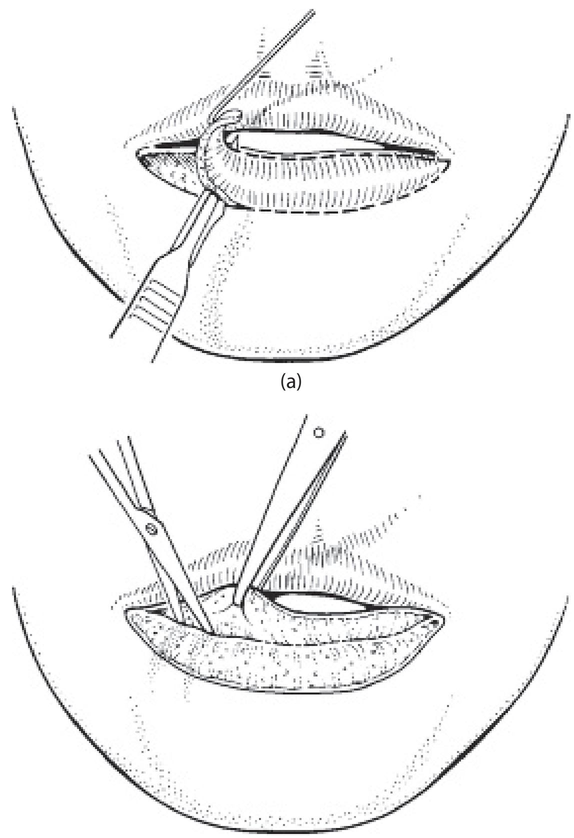


Figure 38.1 Tumour is marked with a 5-mm margin and the vermilion skin junction on each side temporarily tattooed with two dots using methylene blue. This allows accurate suture and alignment post-resection.

Figure 38.2 In a larger tumour the 'V' excision may compromise oncologic margins. Parallel excision as in this 'W' excision is preferred.



(a)

(b)

Figure 38.3 (a) The vermilion is excised in toto from wet line to vermilion-skin margin using a blade (a needle-tipped cautery may also be used). (b) Undermining the oral mucosa with scissors to the depth of the sulcus to allow tension free advancement to reconstruct the vermillion.

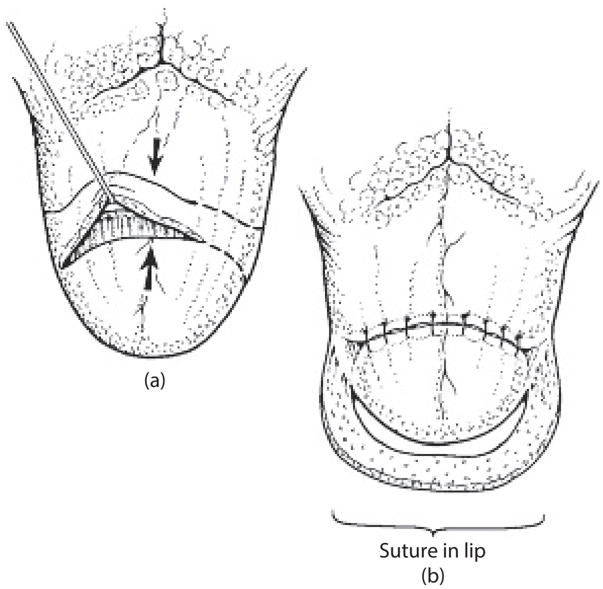


Figure 38.4 (a) Raising the bipediclled flap from the dorsal tongue. (b) The bipediclled flap is passed anteriorly like a 'bucket handle' to be sutured to the vermillion defect. The tongue is primarily closed.

surgically separated 2–3 weeks later. Facial artery musculo-mucosal (FAMM) flap is also a good choice to reconstruct the skin-vermillion area.

Lesions requiring one-third to two-thirds of the lip reconstructed

For these lesions, a 'stepladder' reconstruction gives the best results (Figure 38.5). This method is well suited for lesions in the lateral portion of the lip not involving the commissure. In this flap design, each line of the incision is of equal length. This line follows the submental crease. This incision is carried out once the tumour has been resected. It is carried through skin but leaving the mucosa intact. The flap is then advanced to close the defect. Since this incision is placed in the submental crease, the incisions are well hidden once healed.

For those lesions involving the commissure of the lip, McGregor variation of the fan flap is preferred (Figure 38.6). The tumour is excised as a square as depicted in the image. Two squares are designed as described in Figure 38.6, these are full thickness flaps. This is then rotated into the defect with the pivot point being the commissure. The remaining defect is closed primarily. The vermilion is recreated by local mucosa advancement.

Lesions requiring two-thirds to total lip reconstruction

For this type of defect, the best option is the Fries modification of the Barnard flap (Figure 38.7). The tumour is removed as a rectangle. Local flaps, which are full thickness, are advanced by incisions in the submental crease.

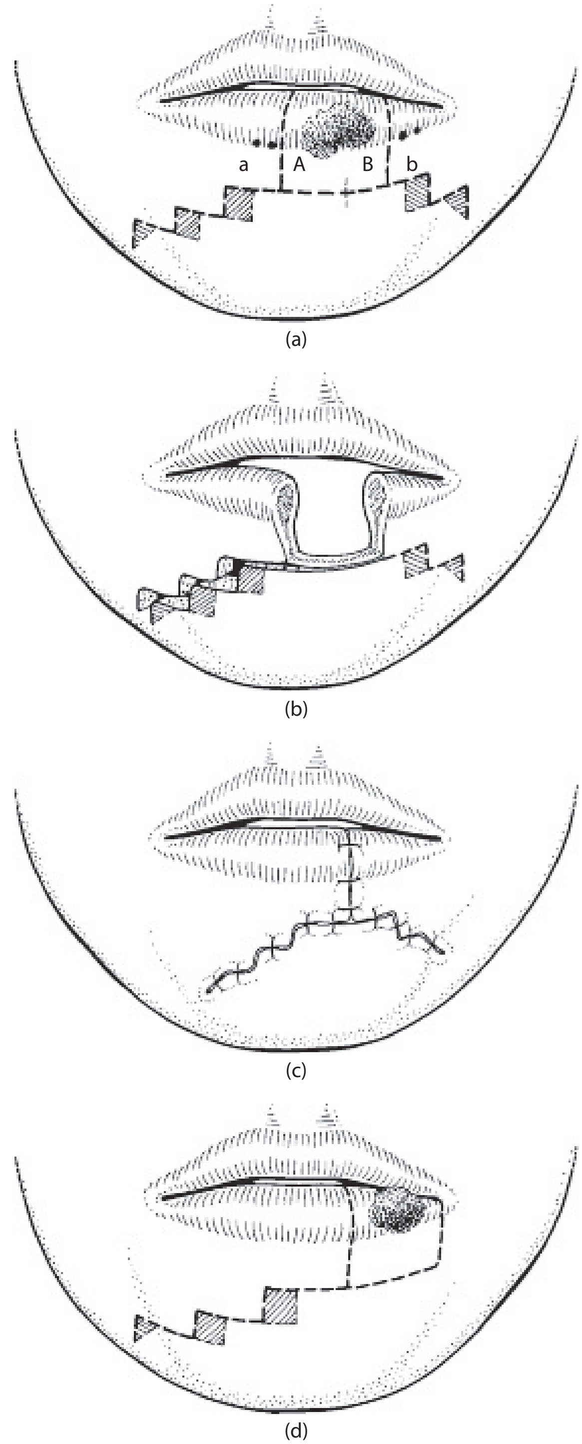


Figure 38.5 (a) Markings for flap, see text for explanation. (b) The tumour has been excised and the flap raised full thickness through skin and muscle. The mucosa can be left intact. Excess skin is removed in shaded areas to prevent 'dog ears'. (c) Closure. (d) Unilateral flap for lateral lesion.

A Burrow's triangle in the nasolabial crease can be excised to prevent bunching of the tissue. The amount of the tissue removed is determined by the bunching created when the orbicularis oris is re-approximated. When creating these incisions on the cheek, the mucosa remains intact and the

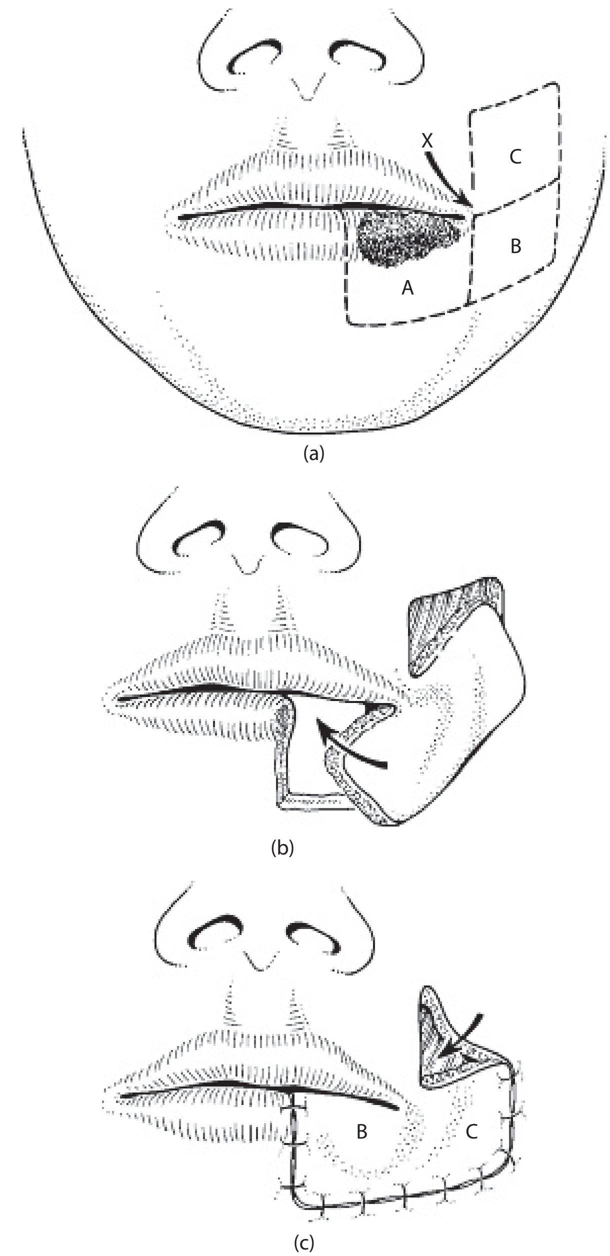


Figure 38.6 (a) Flaps drawn out, blood supply enters at point X. (b) Following tumour excision, square B is rotated to the defect and replaced in position by square C. (c) The loose cheek tissue superior to square C closes the defect in the nasolabial area.

tissue is undermined to allow for movement. The commissural sphincter must be recreated to prevent drooling. This flap works well in older patients with laxity of the skin. However, if the skin is too tight not allowing for much advancement, a free flap must be considered.

Tumours of the floor of mouth

When planning the resection margins for floor of mouth tumours, the elasticity of the tissue can be misleading. It is best to mark out the margins when the area is relaxed

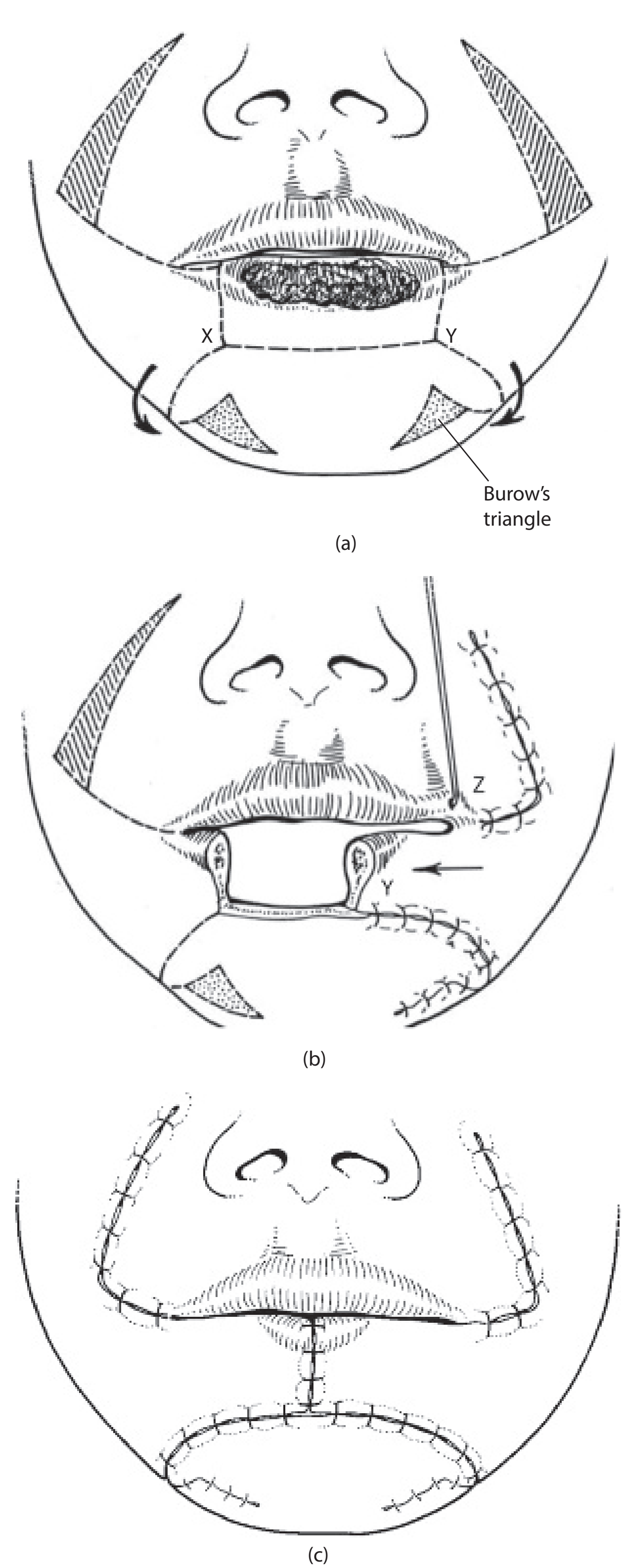


Figure 38.7 (a) Planned rectangular excision, with shaded areas representing Burow's triangles where skin will be excised in the nasolabial and submental regions to allow flaps X and Y to advance without 'bunching and dog ears'. (b) Flaps X and Y advanced to reconstruct the lip. Large '0' prolene non-resorbable suture is placed to suture upper lip and lower lip orbicularis muscles together to reconstruct commissure and prevent drooling. (c) Flaps sutured in layers.

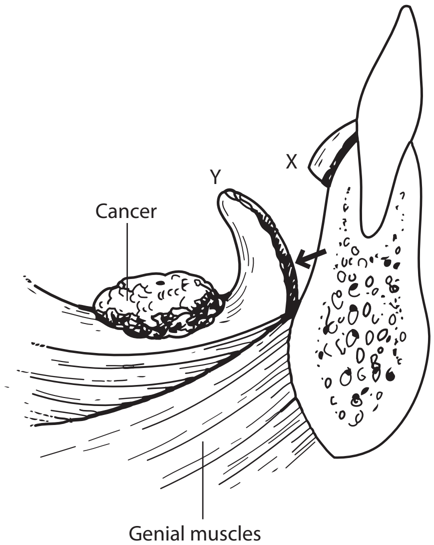


Figure 38.8 Lingual incision of mucosa (point X) and then of periosteum at site of arrow to allow mobilization of the floor of mouth and visualization of a floor of mouth cancer close to the lingual mandible.

to ensure adequate margins. Tumours encroaching on the lingual aspect of the mandible can make resection difficult as well as reconstruction. This is even more pronounced in the dentate patient. In such cases, it is best to start at the mandible, by incising the mucosa and stripping off the periosteum from the mandible. This is a good way to evaluate the mandible for erosion by the tumour abutting the mandible. For these cases, the periosteum is a good surgical margin (Figure 38.8).

If a neck dissection is not planned at the same time and the tumour margins will involve the submandibular duct, then sialodochoplasty of Wharton's duct is necessary. The duct is medial to the sublingual gland. The proximal end of the duct is tagged with a 6-0 nylon suture so that it will not retract into the soft tissue. The tumour is then resected and oriented for the pathologist.

At this point, the duct needs to be re-positioned posteriorly. An opening into the mucosa of the floor of mouth about 1 cm behind the resection margin is made. The tagged duct is then passed through the opening. The orifice of the duct is 'fishtailed'. This is then sutured to the mucosa with 6-0 nylon sutures (Figure 38.9). The patency of the duct is tested. This is important so that an obstruction is not missed. In a context of a malignancy, an obstructive sialadenitis can be confusing and mistaken for a malignant node.

Tumours of the palate

Most tumours of the palate are salivary gland in origin and most of the time they are low grade. They usually do not involve the palatal bone. They occur mostly at the junction of the hard and soft palate. The resection margins usually involve

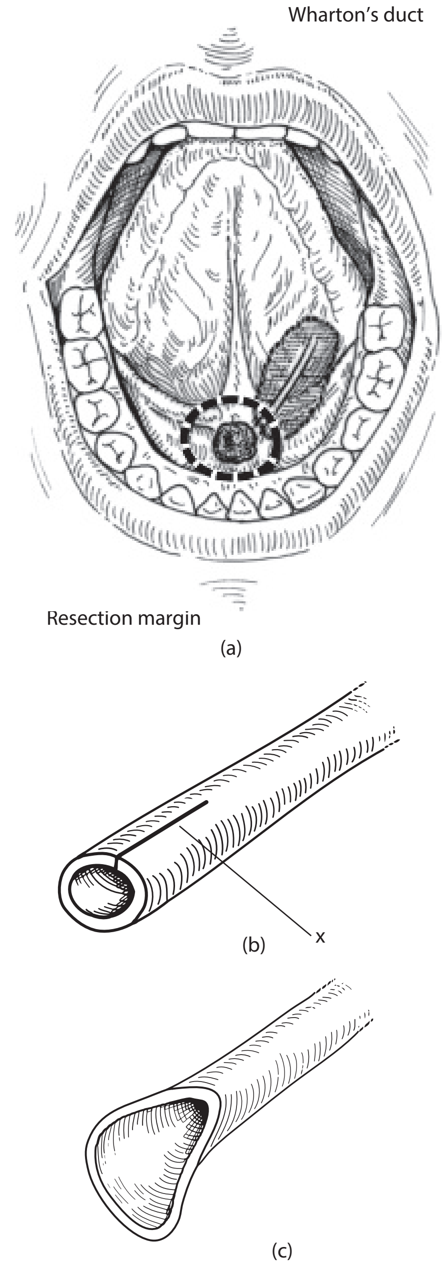


Figure 38.9 (a) Proposed resection will transect Wharton's duct which will require repositioning. (b) and (c) 'Fish tail' sialodochoplasty.

the greater palatine foramen and the greater palatine artery. In these cases, resection of the periosteum and visual inspection of the bone for erosion is appropriate (Figure 38.10).

Similar to the other resections described in this chapter, a 1-cm margin is outline. Typically, this will involve the greater palatine foramen. This area is then outlined with the needle-point diathermy. First, the medial aspect is incised to bone. This is followed by the next incision which is adjacent to the alveolus. The anterior margin is then incised to bone. At this time, a periosteal elevator can be used to elevate the tumour off the palatal bone. Hopefully the greater palatine vessels are still intact and then can be clipped with hemo-liga clips or ligated. If this is not the

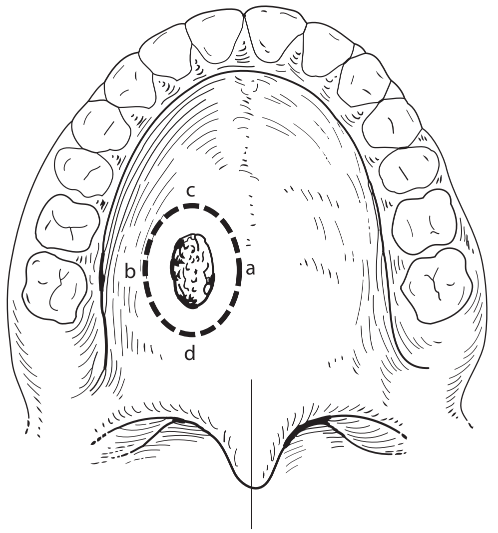


Figure 38.10 Excision of palatal tumour, see text for explanation.

case, then the foramen can be cauterized to control for bleeding. The specimen is then dissected posteriorly to the soft palate. Here is it elevated off the palatal muscles. The specimen is oriented before being sent to the pathologist. The defect can be closed with a buccal fat pad, a healing stent is also a good option, and local flaps may also be used.

Tumours of the tongue

Tongue cancer is the most common oral cancer and tends to behave aggressively. Deep muscle invasion is seen early. Here wide resection margins of 1.0–1.5 cm are acceptable as well as adequate depth of resection. Tumours of the anterior two-thirds of the tongue are respectable via an intra-oral approach. More posteriorly located tumours may require a lip split mandibulotomy, pull-through or transoral robotic surgery (TORS). The surgical resection margins are outlined with a marking pen followed by needle-point electrocautery. The excision of the tumour is then carried out using a combination of blunt and sharp dissection. It is important to always point the needle tip or scalpel blade away from the tumour while excising the tumour. By angling the needle tip away from the tumour, it allows for safe and deep resection margins by accounting for tendency for the muscle to stretch during retraction and spreading (Figure 38.11).

Most small tongue cancers can be closed primarily. The key point to closure of the tongue is to maintain adequate length for speech. The deep muscles are closed in layers with everting mattress sutures on the mucosa. Wound dehiscence is common with glossectomy due to muscle pull. There are other options for closure of tongues. These will take into consideration the size of the defect and the ability of the tongue to have adequate mobility to allow for speech and swallow. Skin grafts, radial/ulnar forearms flaps, submental island flaps, supra-clavicular flaps are all viable options for tongue reconstruction.

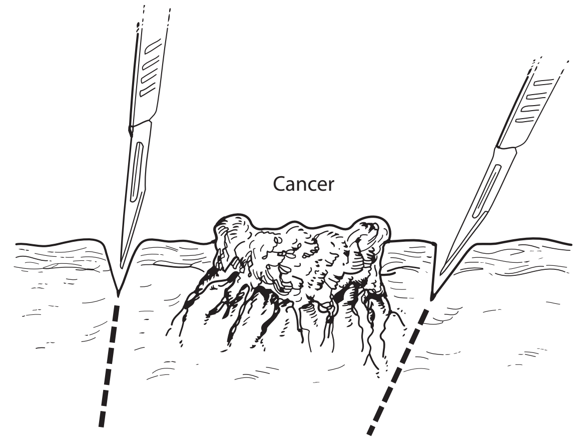


Figure 38.11 (a) Correct and (b) incorrect angulation for tumour excision.

RECONSTRUCTION

In considering the reconstructive options for small oral defects, most sites are satisfactorily dealt with by primary closure, skin grafting or local flaps. In larger cases where microvascular free flaps are not being utilized but imported tissue is required, there are a number of useful local pedicle flaps available to the surgeon e.g. buccal fat pad (Figure 38.12). This section reviews of submental island and FAMM flaps.

Submental island flap

The submental island flap is based on the submental branches of the facial artery and the anterior facial vein. It is an excellent donor site with low morbidity and provides thin pliable skin for reconstruction the lower two-thirds of the face. Caution is advised when using this flap for reconstruction of defects acquired after resection of malignant tumours. For tumours which drain into the submental triangle, a neck dissection is warranted.

In an elderly patient, with laxity of the skin, a sizeable skin paddle can be harvested. A skin paddle as large as 15 cm × 7 cm is available. The pinch test is to determine the ease of closure. The skin paddle is outlined starting with the superior incision ‘a’ which is made approximately 1–1.5 cm below the chin (Figure 38.13a and b). This incision is carried to the angle of the mandible approximately two-finger widths from the inferior border. This incision can be incorporated into a neck dissection. The incision is carried down to the sub-platysmal plane and care taken to preserve the marginal mandibular nerve. The inferior incision ‘b’ is determined by the pinch test and the amount of tissue need to be harvested.

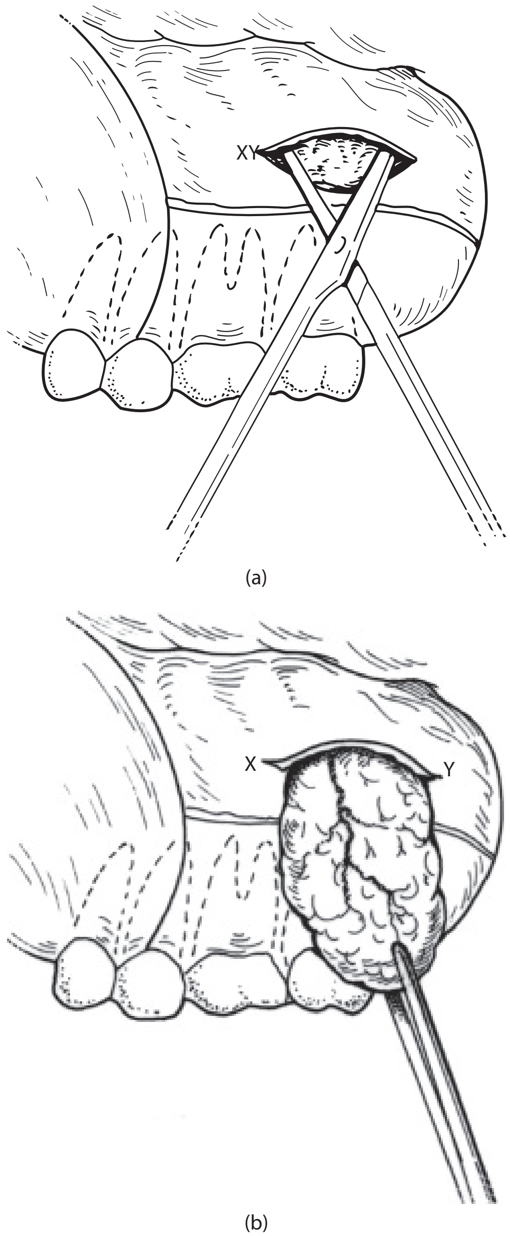


Figure 38.12 (a) Mucoperiosteal flap reflected and horizontal incision opposite the maxillary second molar allows access to the buccal fat pad. (b) Using a clamp or scissors to spread the tissues around the fascia of the buccal fat pad flap allows the pad to be mobilized or prolapsed into the mouth to reconstruct palatal/maxillary defects.

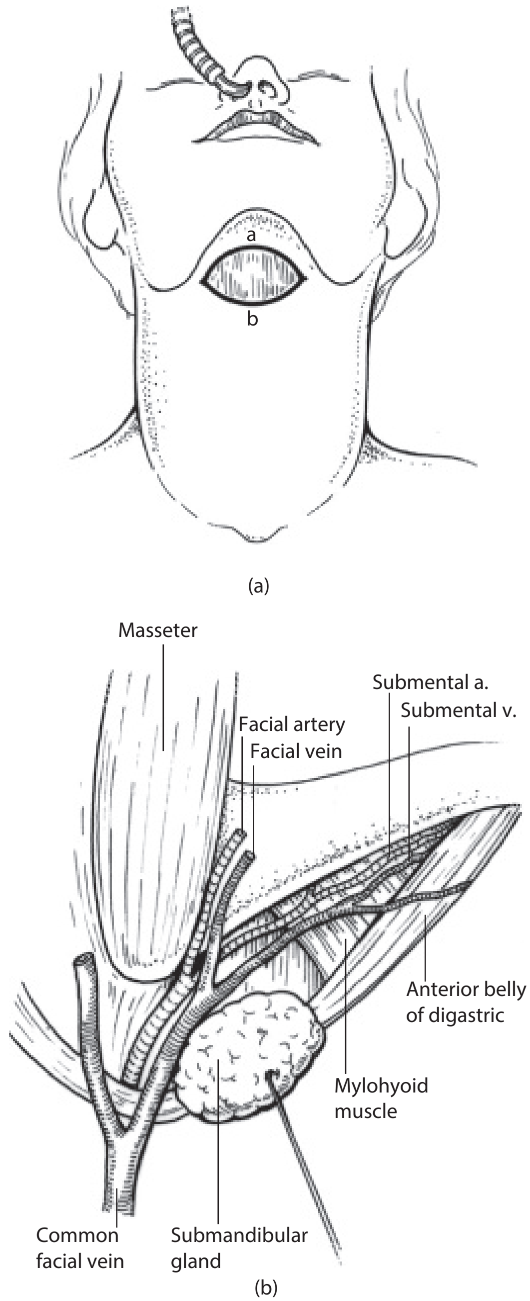


Figure 38.13 (a) Skin flap marked in submental region (see text for details). (b) Usual anatomical distribution of submental vessels.

The flap is harvested by identifying the facial artery and vein, as they are posterior and medial to the submandibular gland. The submental vessels are identified running horizontally and superficial to the mylohyoid muscle and close to the inferior border of the mandible. Perforators to the skin can sometime pass through the anterior belly of the digastric muscle. Since 70% of the time, this occurs the anterior belly of the digastric muscle is harvested with the flap. The flap can be rotated into the oral cavity. The arc of rotation can be improved by dissecting the proximal portion of the facial artery and vein (Figure 38.14a through c).

FAMM flap

This flap is based on the facial artery which crosses the cheek from the gonial notch of the mandible anterior to the masseter muscle to the alar nasi. It is lateral to the buccinator muscle. Although mostly the vein runs

(a)

(b)

(c)

Figure 38.14 (a) Patient with desmoplastic melanoma of the parotid for sentinel node biopsy + selective neck, parotidectomy with skin resection and submental flap marked out. (b) Island flap based on submental vessels. (c) Flap inset to show good arc of rotation for lower face.

with the artery, this is not always the case. Above the inferior border of the mandible, the vein diverges from the artery and lies up to 15 mm posterior to the artery. The drainage of the flap is not dependent of the vein since it is not always incorporated into the flap. This is accomplished by the buccal plexus of veins. The flap can be superiorly based or inferiorly based depending on the site to be reconstructed. This musculomucosal flap can be used to reconstruct the palate, retro molar fossa, alveolus and lip.

The Doppler is used to outline the course of the facial artery. The flap is elevated by carrying the incision to the buccinator muscle at the level of the artery where the facial artery is ligated. This 1–2 cm wide tissue can be raised making sure that the facial artery is included with the flap. It can then be rotated to close the required defect (Figure 38.15).

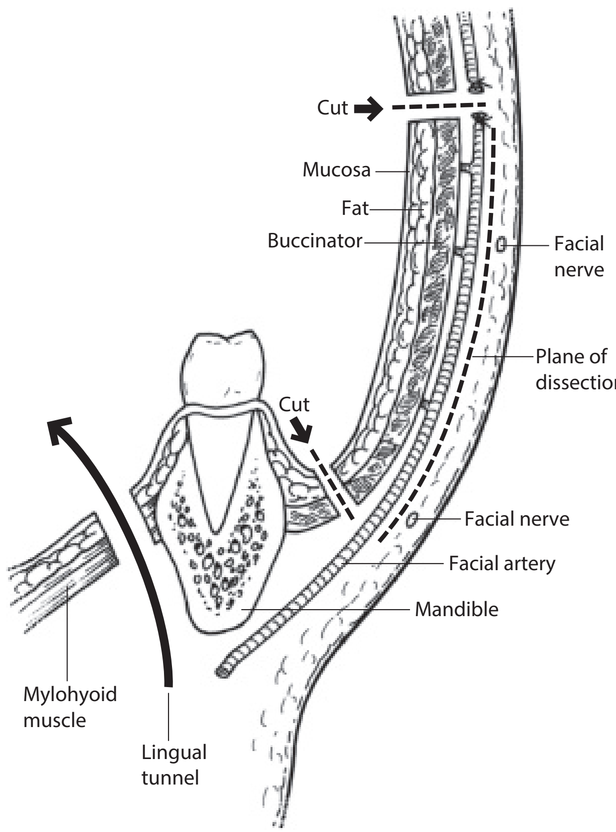


Figure 38.15 Section through cheek in premolar region to illustrate anatomy of facial artery musculomucosal (FAMM) flap. Dotted line is deep margin lateral to buccinator and facial artery. The two small arrows show full thickness incision superiorly with ligation of the facial artery. The inferior incision is through mucosa and muscle only preserving the vessels and developing a mucosal island flap. The flap is mobilized into the neck and transposed to the floor of mouth/tongue via a tunnel created by sectioning the mylohyoid muscle from the lingual mandible.

POST-OPERATIVE CARE

In the immediate post-operative care, the airway needs to be assessed. If considerable swelling is anticipated, the endotracheal tube can remain in place or a tracheostomy should be considered. All flaps, pedicled or free should be monitored for congestion or ischemia. If the airway is not compromised, depending on the reconstruction, feeding option needs to be considered. Sometimes the authors prefer to place nasogastric feeding tubes. There are no occlusive dressings placed on the neck, the authors prefer neomycin ointment at the suture lines. The patient is encouraged to rinse their mouth with chlorhexidine oral rinses after meals.

COMPLICATIONS

The most common complication is bleeding. This can be avoided by adequately drying the field prior to inset of the flap. Also, blood pressure control is necessary in the immediate post-operative phase. In the cases of glossectomy, wound dehiscence is common. When this occurs, it is best to keep the wound clean and allow the area to granulate. If the patient encounters scarring and tethering of the tongue, this can be addressed after several months of healing.

Top tips

- Take time to approximate the skin vermilion border. A small malalignment is very noticeable.
- Use a non-resorbable suture or vicryl to re-approximate the orbicularis oris in lip reconstruction.
- If bleeding is persistent through the greater palatine foramen and electro cautery does not work, consider bone wax.
- When closing tongue defects, take into consideration the distance from the floor of mouth and the amount of tethering anticipated. In some cases, a flap will give better outcome than primary closure.
- The deep margin is the most worrisome in tongue cancers. A recurrence there is difficult to identify and has poor outcomes.

SUGGESTED READINGS

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39

Jaw resection

JAMES S BROWN

CONTENTS

RESECTION OF THE MANDIBLE AND MAXILLA

General principles

This chapter concentrates on the resection of squamous cell carcinoma arising in the oral cavity or the midface. A similar approach is required for the resection of bone invaded by malignant salivary tumours but the points on the patterns of tumour invasion and entry may be different. The principles of the resection techniques may be appropriate to the management of odontogenic tumours especially if these are recurrent. Resection of the jaws for osteoradionecrosis or osteonecrosis is more of a debridement requiring the resection of bone back to a bleeding base prior to reconstruction. Bone resection for osteosarcoma or primary intraosseous carcinoma requires a more radical removal of bone as the tumour will invade the bone preferentially.

Applied anatomy

Mandible

The mandible provides a bony framework to hold the teeth and sensation to the lip and chin is provided by the inferior alveolar nerve which enters at the mandibular foramen and exits at the mental foramen. Although there are often attempts to preserve this nerve in the treatment of benign disease, the loss of sensation to the lip and chin is an acceptable morbidity for most patients. The relationship of the teeth to the bone varies with patients and the molars run from a buccal position to a more lingual position posteriorly. The temporomandibular joint articulates with the skull base and in some cases the condylar head may require resection. The loss of teeth results in the loss of the supporting alveolar bone. The inferior alveolar nerve will come to lie on the alveolar ridge and the relationship of the floor of mouth muscle insertions will alter with the loss of bone (Figure 39.1 and 39.2).

Maxilla

The maxilla is a complex structure which provides bone for the upper dental arch supports the alar base and facial curtain as well as providing the orbital floor, malar buttress and lateral nasal wall. The articulation with the rest of the skeleton is important to understand in tumour resection.

Medially, the lateral nasal wall is the least important structure, but care is required in maintaining the lacrimal system. The frontal process of the maxilla and the nasal bones articulate with the frontal bone and immediately behind these structures is the ethmoid sinus and then the sphenoid sinus. The cranium lies directly above these bones and experience in skull base resections is required to safely resect these structures. The lamina papyracea of the medial wall often requires resection and care must be taken to identify the anterior ethmoidal artery in particular. The maxilla provides much of the orbital floor as far as the inferior orbital fissure, and more laterally the lateral wall is made up of the greater wing of the sphenoid and the malar.

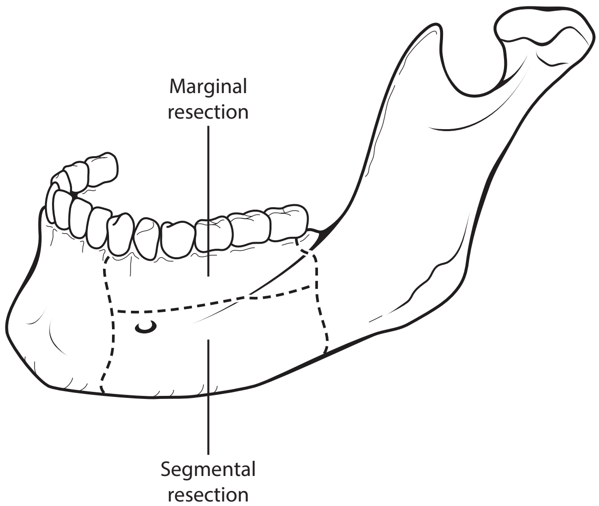


Figure 39.1 A rim or marginal resection maintains the lower border and a segmental resection requires the full thickness of the mandible to be resected.

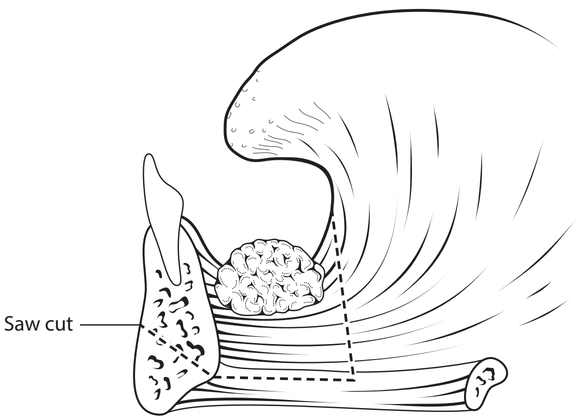


Figure 39.2 The commonest form of rim resection is coronal. This figure illustrates the method used to enter the floor of the mouth deep to the tumour to obtain a clear margin even though the bone is not invaded.

MANDIBULAR RESECTION FOR ORAL SQUAMOUS CELL CARCINOMA

Patterns of invasion and routes of tumour entry

Early or shallow invasion of the mandible from the oral cavity will often show an erosive pattern with a pushing front and a connective tissue layer separating the bone from the tumour. The more infiltrative pattern is related to deeper invasion in which the connective tissue layer is lost and separate islands of tumour infiltrate in a less favourable manner.[1–3] It is not possible to predict the pattern of invasion so the judgment on how much bone to resect remains clinical and based on imaging. Various theories of the route of tumour entry to the mandible have been suggested but it seems most likely that the tumour enters the mandible at the point of contact. In the dentate mandible, this tends to be at the junction of the attached and reflected mucosa and in the edentulous mandible, this is more likely at the crest of the ridge due to the lowering of the floor of the mouth due to the loss of teeth.[2,4] These are important issues if a marginal or more conservative resection of the mandible is being considered.

Table 39.1 Summary and comparison of the imaging techniques and clinical examination.

Imaging technique	No of reports	Specificity (mean)	Sensitivity (mean)
Clinical examination	9	66	81
Plain radiography	18	81	76
Bone scintigraphy	15	74	93
SPECT	3	65	97
Computed tomography	7	88	78
DentaScan	3	–	–
Magnetic resonance imaging	4	86	81
Ultrasound	2	93	86

Abbreviation: SPECT, single photo emission computed tomography.

Pre-operative assessment

There are multiple papers looking at the accuracy of pre-operative imaging techniques and their accuracy in predicting the presence of tumour invasion of the mandible. A recent review article has summarized the findings which are included in Table 39.1.[5]

A widely accepted standard is to use a magnetic resonance imaging scan (MRI) as a standard image of the primary tumour and the neck nodes. This will usually provide 5-mm slices and will include T1, T2 and fat suppression sequences as well as gadolinium enhancement. The fat suppression sequence is the most sensitive in indicating tumour invasion of the mandible. The only additional image would be an orthopantomogram (OPG) if there is clear invasion of the mandible or in which the mandible is unlikely to be invaded. For tumours in which it is unclear if the mandible is invaded a single photon emission computerized tomography (SPECT) scan is included to get a further sensitive imaging of the mandible. The combination of an image with a high specificity with one with a high sensitivity can provide a reasonably accurate prediction of the extent of mandibular invasion and therefore the most appropriate method of resection. Cawood and Howell published a widely accepted classification of the mandible following the loss of teeth and it is clear that in Class V and VI mandibles (Figure 39.2) there is insufficient height of bone to safely perform a marginal resection for malignant disease. As a result, a guide to mandibular resection has been published which relates to the size of the mandible and the results of the investigations predicting bone invasion (Table 39.2).

Table 39.2 Results of the investigations predicting bone invasion.

Mandible classification	OPG−, MRI−, BS− No invasion/periosteal invasion	OPG− MRI or BS+ early invasion (<5 mm)	OPG+, MRI+, BS+ late invasion (>5 mm)
1–2 (dentate)	Rim	Rim	Rim/segment
3–4 (>20 mm mandibular height)	Rim	Rim/segment	Segment
5–6 (<20 mm mandibular height)	Rim/segment	Segment	Segment

Abbreviations: BS, bone scan; MRI, magnetic resonance imaging; OPG, orthopantomogram.

Methods of mandibular resection

In the past, the 'commando' operation in which the body of the mandible was sacrificed to remove potential lymphatics containing tumour and to facilitate the soft tissue reconstruction has now been discontinued and yet there are series published in which only 29% of the resected mandibles were invaded by tumour.[6] As in all oncological surgery, the aim is to cure the patient of disease through adequate resection. At the same time, the skilled surgeon should be trying to reduce the morbidity of the operation to a minimum and maintain the best possible function. Good functional results for patients depend more on the tissue left behind than the method of reconstruction.

There are two basic methods of mandibular resection. In the marginal or rim resection, the integrity of the lower or upper border of the mandible is kept intact (Figures 39.1 and 39.2). In the full or segmental resection of the mandible, both the upper and lower border are included in the resection so that there is a loss of continuity of the mandible. There is clear evidence to show that functional and aesthetic results are poor if the continuity of the mandible is not restored.[7] The need to reconstruct the mandible to achieve the best functional and aesthetic result will often involve composite-free tissue transfers for malignant disease which will add to the donor site morbidity and increase the risk of flap failure.[8,9]

Marginal or rim resection

A marginal resection of the mandible can be performed in the coronal or the sagittal plane. In the majority of cases, a coronal marginal resection is used (Figure 39.2). This is the standard method for tumours in which a margin of normal bone is required. It can be used for smaller odontogenic tumours in which there is sufficient residual bone to maintain the lower border. A sagittal marginal resection cannot be used for bone pathology as preserving any kind of margin is not possible. It has been used for floor of mouth squamous cell carcinomas to obtain a clear margin when tumour is abutting the mandible but not obviously invading. This is a high-risk strategy as any invasion

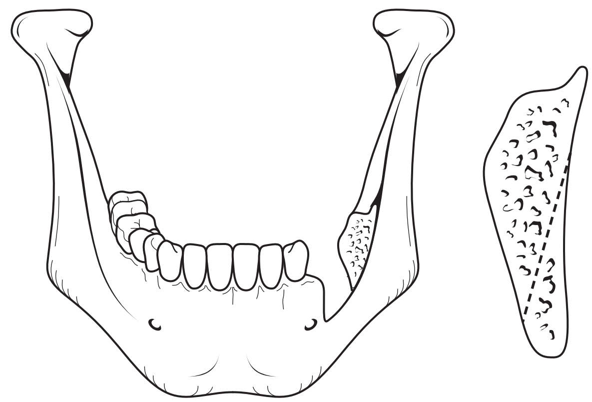
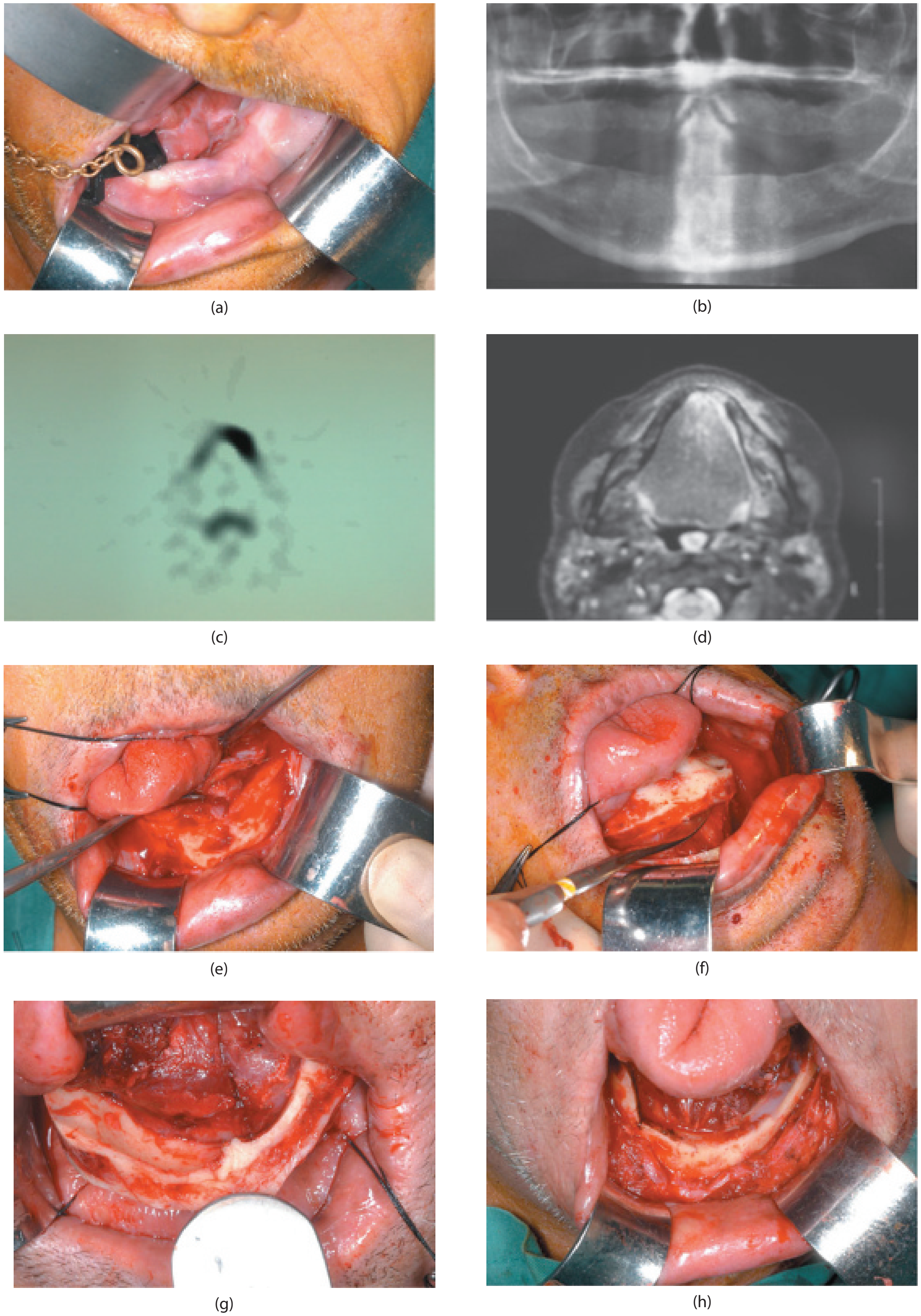


Figure 39.3 This is a partial sagittal rim resection but this diagram illustrates the angle of the body of the mandible from medial to lateral if the full sagittal rim is required.

through the cortex will be reported as an involved margin. In addition, the angle of the mandible in the body region is difficult to judge (Figure 39.3). In this situation, it is a safer oncological approach to perform a segmental resection of the mandible. Rim resections that involve the ramus of the mandible can only be done in the coronal plane as the ramus is too thin to split for oncological reasons, and it is best to include the coronoid process as this may reduce trismus post-operatively.

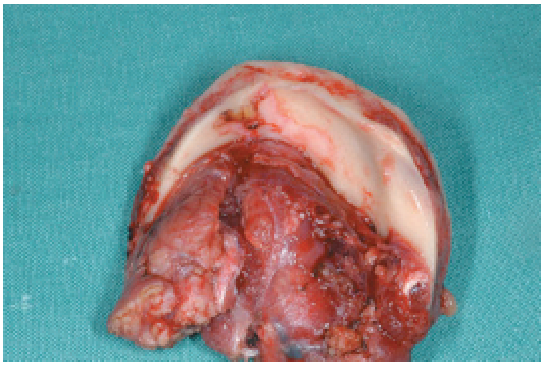
If the lower border of the mandible is to be preserved then 10 mm of the depth of bone will be necessary for jaw continuity to be reliably maintained.

For marginal resections involving malignant disease (all osteosarcomas and primary intraosseous carcinomas require segments), it is possible to assess the extent of tumour invasion into the mandible from the surrounding soft tissues and estimate the extent of the resection required. This technique is illustrated through Figure 39.4. Note that periosteal stripping to assess the presence of mandibular invasion and its extent has been used. The use of periosteal striping is an essential part of the technique in the decision-making process for mandibular resection. It has been shown to be a reliable technique[3] and in a large series from the unit in Liverpool our involved bone margin rate is very low compared to the soft tissue margin rate.[10]

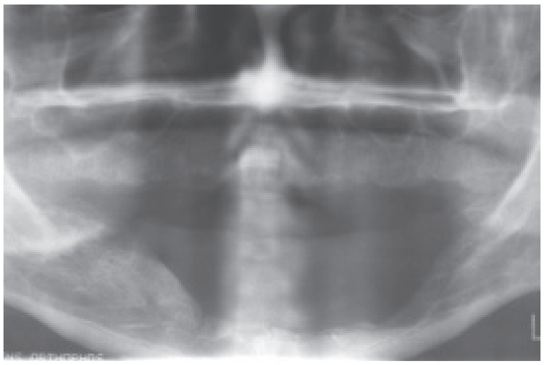


(a) (b) (c) (d) (e) (f) (g) (h)

Figure 39.4 (a)–(d) Pre-operative clinical photograph, OPG, SPECT scan and MRI scan showing early tumour invasion of the mandible. (e) The resection of the buccal side of the mandible. (f) Completion of the planned coronal rim resection. (g) Turning the bone over to inspect the lingual side of the rim resection and ensure clearance of invaded mandible. (h) The resulting defect post resection. (*Continued*)



(i)



(j)

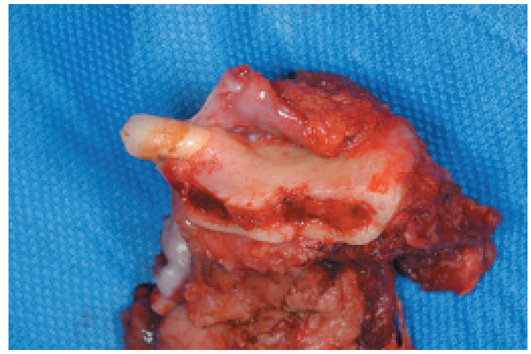
(k)

Figure 39.4 (*Continued*) (i) The specimen with lingual periosteal stripping to confirm clearance of resection. (j) and (k) Post-operative OPG and clinical photograph of anterolateral thigh flap reconstruction.

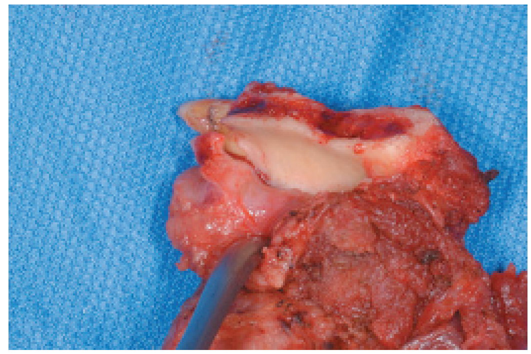
Segmental resection of the mandible

This is a basic procedure in the management of malignant disease once the decision has been made not to preserve any part of the involved mandible. The decision as to where the bone cuts are made will depend on the assessment of mandibular invasion and the entry and exit points of the inferior alveolar nerve. In benign disease, it is often possible to keep the nerve intact and allow it to lie in the soft tissues overlying the reconstructed bone.

Periosteal stripping is also an important factor in the segmental resection of the mandible in malignant



(a)

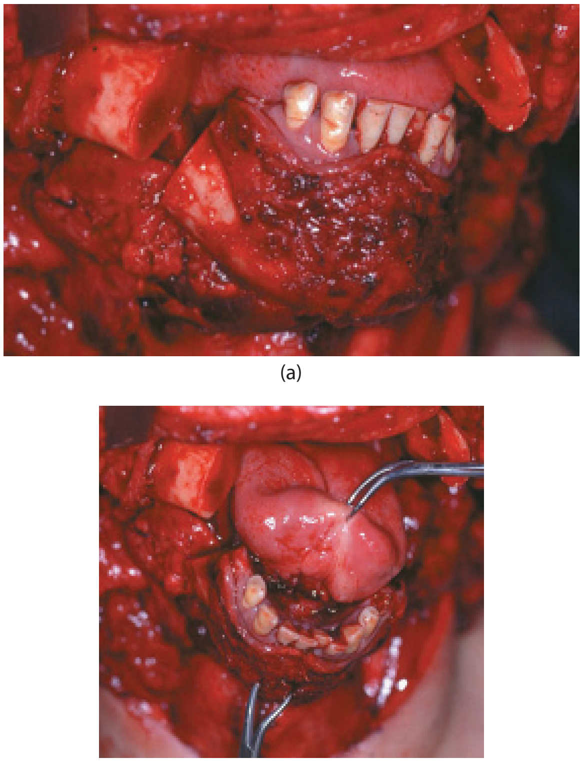


(b)

Figure 39.5 (a and b) Periosteal stripping postresection to ensure that the buccal and lingual surfaces are clear of tumour in the distal part of the resection in the region of the lower right canine.

disease. Periosteum can be striped back from the undamaged bone until it becomes adherent, or the tumour is seen entering the bone. Once this is established, the margin can be decided and the bone cuts planned. It is also important to examine the specimen to ensure that the bone margins are clear of disease by direct inspection (Figure 39.5). This is much less reliable in a malignant tumour arising in bone such as a primary intraosseous carcinoma or an osteosarcoma. In these cases, the periosteum and the cortex of the bone may look clear of invasion as the tumour spreads along the marrow space. As a result, it is necessary to be much more aggressive in mandibular resection and frozen sections should be performed if possible.

It may be necessary to excise the overlying skin in mandibular resection. In most cases, it is possible to preserve the skin cover but care must be taken in the buccal aspect of the resection to take sufficient tissue. It is seldom necessary to use an access procedure with segmental mandibular resection. The overlying skin is raised or excised depending on the needs of the oncological ablation and once the bone cuts have been made the mandible can be delivered into the neck and any further resection lingual to the jaw can be undertaken as the last part of the resection prior to the delivery of the specimen (Figure 39.6).



(a)

(b)

Figure 39.6 (a–b) There is no need for access surgery such as a lip split in segmental surgery as the tumour can be delivered into the neck to complete the resection.

Maintaining the occlusion in mandibular resection

There are various methods used to maintain the occlusion prior to mandibular reconstruction. Some surgeons will use a form of external fixation of the nonresected part of the mandible but this is very cumbersome and the device impedes accurate oncological resection. Templates have been devised using stereolithographic models but again these are often impractical in surgery for malignant disease. The simplest technique is to prebend a plate if the tumour does not involve the buccal aspect of the mandible. In this way, the harvested bone can be grafted into position with the plate already in place. I usually move the plate back by a screw-hole in the edentulous situation to take the pressure off the soft tissues and reduce the risk of dehiscence. If the use of a pre-bent plate is not possible then the condylar position can be fixed with a miniplate from the part of the ramus that does not require resection to the maxilla prior to the resection with the mandible in occlusion. Once the mandible has been resected, the position of the ipsilateral condyle remains fixed and the collateral mandible can be located with the residual occlusion. A plate can then be bent into position prior to the placement of the graft. This can be carried out bilaterally for extensive mandibular resections. The length of the plate may need to be estimated but at least the condyles will be in the correct position relative to each other.

Resecting the ramus and condyle

In most cases of squamous cell carcinoma, it is possible to maintain the condyle and the condylar neck sufficiently to maintain a plate so that this important part of the joint is left in function. The need to resect the condyle makes the subsequent reconstruction more difficult as the condyle cannot be fixed and it is not possible to prebend a plate. The resection of the condyle with the ramus and body of the mandible is relatively straight forward but care must be taken to protect or tie-off the maxillary artery and avoid damage to the facial nerve. The facial nerve can be damaged by inappropriate retraction in this region. It is often necessary to use some form of intermaxillary fixation if the patient is dentate to help the patient maintain a functioning occlusion in the post-operative period.

RESECTING THE MAXILLA

Pathology and pre-operative imaging

There is much less controversy over the more conservative approach to maxillary resection than the mandible. It is possible to preserve the bone of the maxilla with a limited resection of the palatal or alveolar mucosa and place a dressing plate and await the pathology report. If there is an involved or close margin then bone can be resected at a second procedure. This process is also possible in more extensive resections of the maxilla in which an obturator can be placed and again the margins checked and more tissue taken at the time of the obturator change.

There is little discussion on the role of pathology either in terms of the pattern of spread in the bone or the pathway of entry. Most accept that the route of entry in the maxilla is at the point of contact and thus the maxillary resection is guided by the extent of the soft tissue mass.

For the assessment of bone invasion in the maxilla, most prefer a computed tomography (CT) scan. In our practice, both MRI and CT scans are used to fully assess the tumour when there is concern over the involvement of the orbit, skull base or the infratemporal or pterygoid fossa. The CT scan is probably best for the skull base, and the MRI to assess the infratemporal fossa and both contribute equally to the invasion of the orbital contents.

The methods of resection are based on the classification illustrated in Figure 39.7.[12]

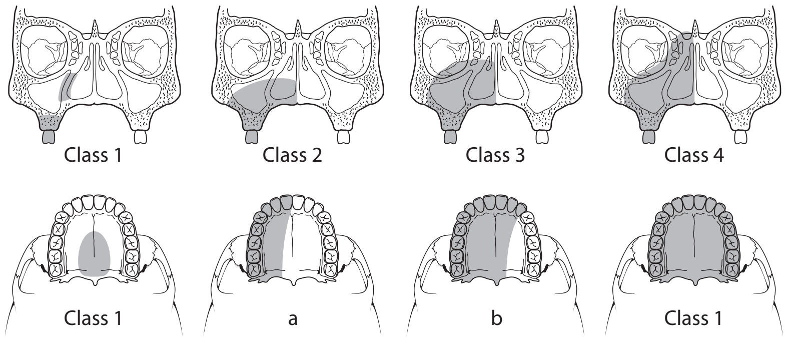


Figure 39.7 Classification of the maxillectomy defect.[11] The need for reconstructive options increases from Class 1 to 4.

Class I (alveolectomy)

For Class I defects (Figure 39.1), there is no need to use an access procedure, as the tumour can usually be visualized with ease. This classification includes a medial maxillectomy often used for inverted papillomas but resection for this pathology is not included in this chapter (Figure 39.8).

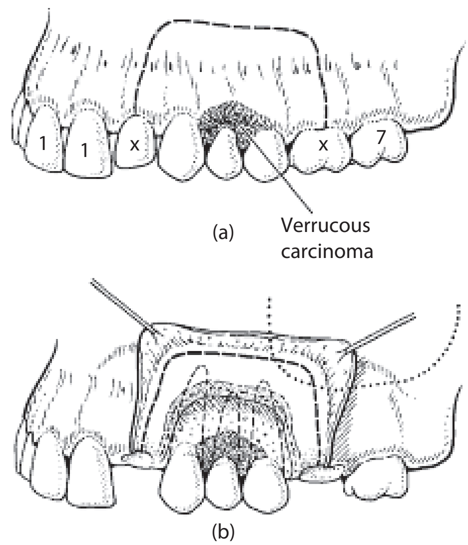


Figure 39.8 An example of a Class 1 type of resection without causing an oroantral fistula. Healing by secondary intention with the use of a dressing plate may be all that is required.

Class II (low-level maxillectomy)

In this situation, the orbital floor is not involved with the resection and if the lesion is below the level of the infraorbital nerve then no access procedure may be required. Either a lip-split combined with a lateral rhinotomy or a midfacial degloving procedure may be used for access with equal effect.[13,14] There are four osteotomies required to deliver the low-level maxilla in ablative surgery:

1. *Vertical alveolar (Figure 39.9a)*: In the dentate maxilla, it is best to remove a tooth in the line of the osteotomy which is continued to the floor of the nose. Maintaining bone adjacent to the remaining tooth helps the stability of the adjacent tooth to the bone cut for obturated cases. Ensure there is sufficient soft tissue to cover the exposed bone.
2. *Le Fort 1 level*: A further osteotomy is required at the required height which may include the infraorbital nerve if required. This is carried through to the pterygoid plates.
3. *Pterygoid plates*: If the tumour is contained in the antrum, the pterygoid plates can be split from the maxilla with a chisel. If the tumour is through the antrum posteriorly it is essential to make a bone cut through the pterygoid plates superior to the position of the tumour and then resect the through the pterygoid muscles to obtain a margin of resection.
4. *Palatal*: The alveolar osteotomy is continued into the palate. If possible, the soft tissue incision should allow some of the redundant mucoperiosteum to cover the bone cut especially if obturation is the method of rehabilitation.

Once these osteotomies have been carried out the hemimaxilla can be mobilized and any soft tissue attachments released.

Class III (high-level maxillectomy maintaining the orbit)

The midfacial degloving technique reaches its limit if the orbital floor requires resection or there is extension into the medial orbital region of the ethmoids. In this situation, the lip split and lateral rhinotomy may be sufficient or it may be necessary to extend the incision as a blepharoplasty incision or sub-ciliary incision (Weber-Fergusson). In most situations, it is possible to reach the lateral orbital wall and malar without this extension reducing the risk of ectropion.

This is the most complex resection because of the need to preserve the orbit and the lacrimal apparatus. A guide to the osteotomies is as follows (Figure 39.10):

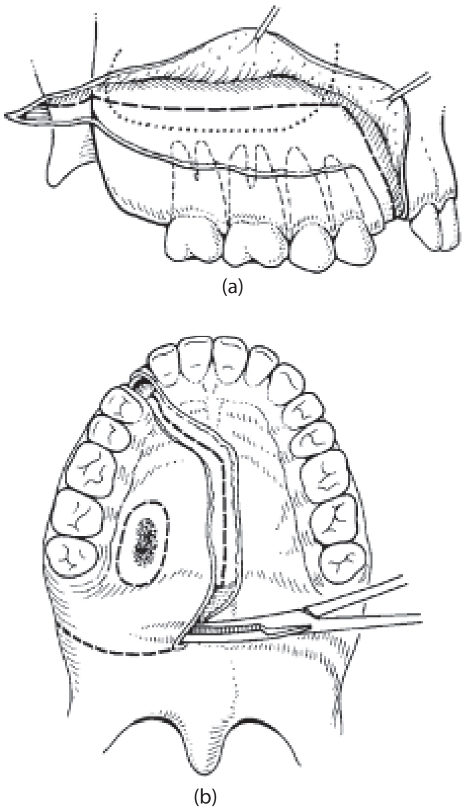


Figure 39.9 (a) The vertical, Le fort 1 level and pterygoid plate resection is shown. (b) This shows the palatal bone cut. It is usually best to remain on one side or other of the nasal septum depending on the extent of resection required. It is also important to ensure there is sufficient redundant mucoperiosteum to cover the bone cuts for obturated cases.

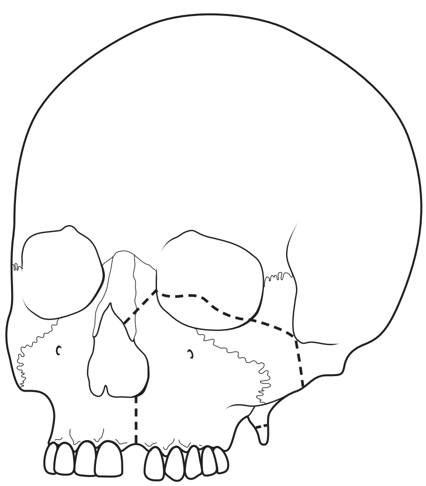


Figure 39.10 Class III. This shows the higher bone cuts required if the orbital floor and/or medial orbital wall require resection.

1. *Vertical alveolar and nasal*: The previously described vertical alveolar bone cut is extended to include the nasal piriform fossa and extended to the level of the lacrimal crest. Care must be taken to expose the lacrimal sac and to preserve this structure.
2. *Orbital*: In this situation, the orbital floor is included as far as the inferior orbital fissure. This horizontal bone cut can be extended to the lateral orbital wall or the frontal process of the malar bone as required.
3. *Malar*: The orbital bone cut is linked to the malar buttress cut which is made lateral to the position of the tumour.
4. *Pterygoid plates*: This often requires the plates to be sectioned higher than in the low maxillectomy close to the skull base. A chisel can be used to fracture off the pterygoid plates with a tumour contained within the antrum.

In these more extensive tumours, this part of the maxillectomy can be delivered intact. In most situations, there will be extension into the ethmoid sinuses or superior to the lacrimal sac which will make delivery of the en bloc specimen more difficult. It is still essential to attempt to deliver the main part of the maxillectomy intact and carry out further resection of the medial orbital wall and ethmoid and sphenoid sinuses as required. If it has not been possible to maintain the lacrimal system, the punctum is stented with a silastic tube and delivered into the nose and tied off. The silastic tube can be cut between the upper and lower punctum at about 3 weeks. It may be possible to repair parts of the lacrimal sac and duct at the time of the resection but the placement of silastic tubes is still important to guide the tear flow as healing takes place.

Class IV (radical maxillectomy with orbital exenteration)

If the orbit requires resection with the maxilla then the approach includes the upper and lower lids if there is no attempt to reconstruct the defect with a prosthetic eye. This operation is much easier to perform as no orbital structures need to be preserved.

In this operation, it is better to release the optic nerve after exenterating the superior part of the orbit after the access procedure.

The same vertical bone cuts are made in the alveolus and nasal bones but no special attention is required regarding the medial canthal ligament and the lacrimal apparatus. The lateral bone cut is made from the inferior oblique fissure to the malar buttress prior to the release of the pterygoid plates. The palatal bone cuts link with the vertical alveolar and nasal cuts and at this stage the specimen can be mobilized. The soft tissue resection at the base of the orbit is completed and now it should be possible to deliver the specimen. Tumour extending into the skull base, the ethmoids and sphenoid sinuses require removal after the delivery of the main specimen.

Tumours involving the skull base require a multidisciplinary team approach. In this situation, a coronal flap, craniotomy and frontal bar osteotomy may be required to obtain adequate access to the anterior skull base.

Top tips

Resection of the mandible

- Pre-operative imaging should include a sensitive (bone scan, MRI) and specific (OPG) technique.
- Pre-operative imaging, clinical examination and the use of perioperative periosteal stripping all help to decide the type and extent of resection.
- Remember that the tumour will invade the mandible at the point of contact which may be below the dental line or the crest of the ridge.
- Early invasion is more likely to be the erosive pattern and late invasion infiltrative, requiring a wider margin.
- The option of a rim resection decreases with the extent of mandibular resorption following the loss of teeth (Class V and VI).

Resection of the maxilla

- Pre-operative imaging will include an OPG and a CT scan and often an additional MRI will be useful to assess the skull base.
- The main issues in maxillary resection involve the removal of the orbit and the extent of the disease into the infratemporal fossa.
- Using a saw to resect the pterygoid plates above the tumour will ensure a safer resection at the posterior maxilla.
- Close cooperation with the restorative dentist is essential in the planning of maxillary resection.

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40

Orbital resection and reconstruction

ALEXANDER D RAPIDIS

CONTENTS

INTRODUCTION

Orbital tumours pose numerous challenges in terms of diagnosis, imaging and management. They can be classified into three main groups according to their origin: (1) primary lesions, which originate from the orbit itself; (2) secondary lesions, which extend into the orbit from neighbouring structures (intra-cranial tumours and tumours of the paranasal sinuses) and (3) metastatic tumours. Orbital tumours are also divided according to their anatomical site into intra-conal and extra-conal.

ORBITAL ANATOMY

The orbit is a pear-shaped bony chamber with an anterior opening measuring approximately 40 and 35 mm in horizontal and vertical diameters, respectively. Its volume expands approximately 1 cm posterior to the bony orbital rim and then gradually decreases towards the apex, which consists of the optic canal at its narrowest diameter. In the axial plane, the medial wall measures approximately 45–50 nm from the anterior lacrimal crest to the optic canal. Posteriorly, the lateral wall is bordered with the superior orbital fissure, situated between the greater and lesser wings of the sphenoid bone. This foramen transmits the third, fourth and sixth cranial nerves and the ophthalmic branch of the fifth cranial nerve, the superior orbital vein and sympathetic nerves.

The peri-orbita is important because it acts as a barrier to the extension of neoplastic growth.

ORBITAL PATHOLOGY

Orbital tumours can derive from tumours of epithelial, mesenchymal, haematologic and nervous origin: vascular tumours, fibrohystiotic tumours, fibro-osseous and cartilaginous tumours, peripheral nerve tumours, haematologic tumours, lacrimal gland tumours, tumours of the lacrimal drainage system, eyelid and peri-ocular skin tumours, conjunctival tumours, ocular tumours, tumours of the cranial and nasal cavities, brain tumours and metastatic tumours.

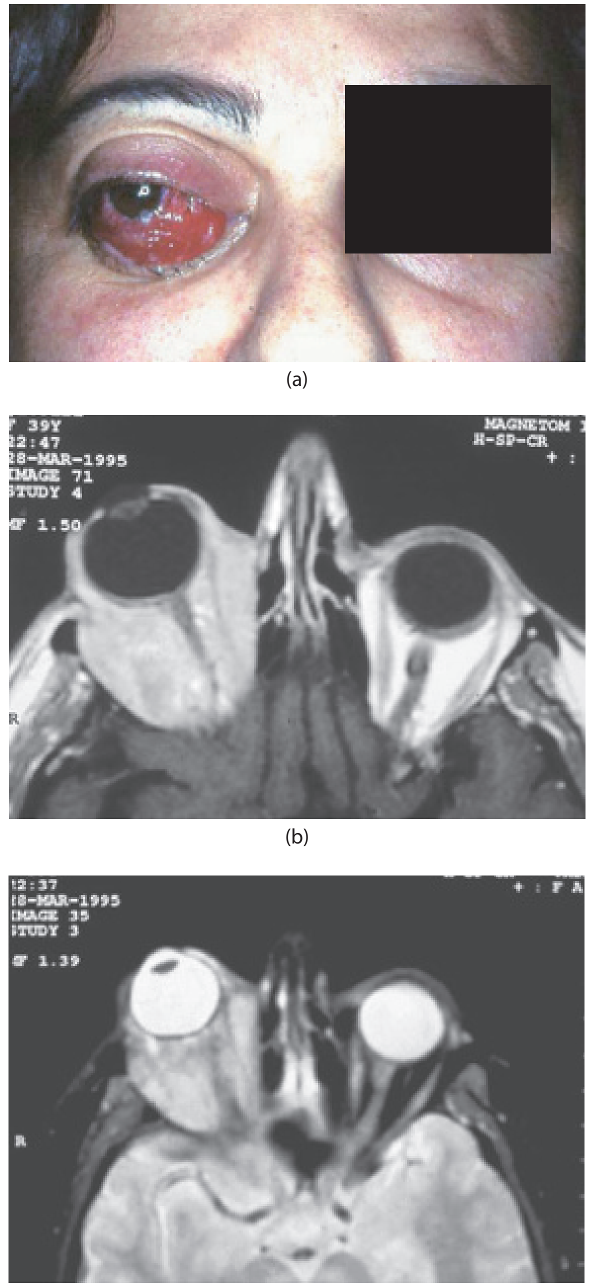
Orbital lymphoma is the most common malignant tumour of the eyes. It can occur either as the primary

site of disease or rarely as a secondary site of systemic non-Hodgkin lymphoma (NHL). Orbital lymphoma typically is a disease of the elderly as the majority are non-Hodgkin's type and are seen primarily in adults in the 50–70-year age group.

Malignancies of the ocular adnexa are the most common reason for orbital exenteration and include squamous cell carcinoma (SCC), sebaceous cell carcinoma and basal cell carcinoma (BCC). Other less common tumours include conjunctival malignant melanoma, adenoid cystic carcinoma of the lacrimal gland and uveal melanoma with extra-scleral extension.

Lacrimal gland lesions can be classified as epithelial and non-epithelial lesions. Epithelial tumours can be benign (e.g. pleomorphic adenoma) or malignant (e.g. adenoid cystic carcinoma). Conjunctival melanoma is a rare but aggressive ocular tumour. The most common primary malignant intra-ocular tumour in adults is uveal melanoma, whereas in children it is retinoblastoma. Rarely, intra-ocular tumours extend transclerally and invade the peri-ocular tissues and the orbit. The uveal melanoma originates from the monocytes of the uvea and has the capacity to invade the adjacent tissue structures aggressively and metastasize systemically.

A variety of pathologies can involve the preseptal space. Frequently these tumours are benign, for example, xanthelasmas and tumours of limited malignancy. Rare tumours include capillary haemangiomas, lymphomas and orbital metastases from distant sites.



(a)

(b)

(c)

Figure 40.1 (a) Clinical photograph of a patient with orbital lymphoma. There is marked proptosis with chemosis of the conjunctiva. (b) Magnetic resonance imaging (MRI) (T2 weighting) showing diffuse infiltration of the occulomotor muscles from the lymphoid tissue. (c) MRI (T1 weighting) depicting the same radiological findings. There is marked enlargement of the rectus muscles.

CLINICAL SIGNS AND SYMPTOMS

The most important feature is proptosis. Slowly growing masses of the orbit usually do not alter the anatomic relationship of the eyelids to the globe and extra-ocular motility is affected only at extreme gazes (Figure 40.1).

Lacrimal gland tumours typically present with upper eyelid fullness, alteration of eyelid contour, and downwards and nasal displacement of the globe.

There are two mechanisms by which a tumour can cause diplopia: first, by infiltrating the nerves supplying the extra-ocular muscles, as seen with malignant tumours, and second, by restricting the normal extra-ocular motility function and/or deviating the axis of the eye.

Infiltrating tumours have a tendency 'freeze' the eye in the primary position of gaze because of their indiscriminate infiltration into the muscles and the soft tissues of the orbit (Figure 40.2).

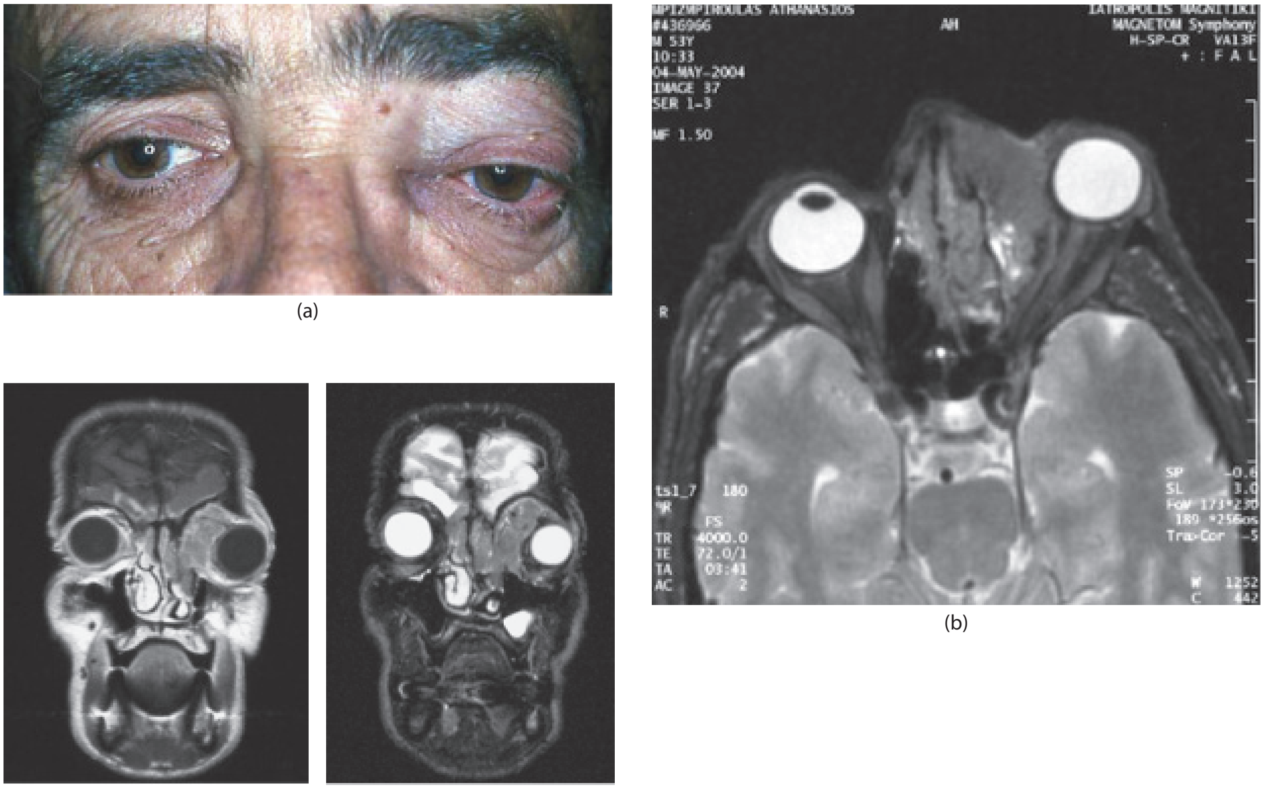
Uveal melanomas have an early sign impairment of visual acuity (Figure 40.3).

Primary lacrimal sac lesions, or those affecting the lacrimal sac as part of a systemic process, present with epiphora, dacryocystitis or a hard, fixed mass arising above the medial canthal tendon, sometimes with serosanguinous tears.

Intra-cranial tumours may rarely extend into the orbit. Orbital extension may produce ophthalmoplegia, optic neuropathy and proptosis.

RADIOLOGICAL DIAGNOSIS OF ORBITAL TUMOURS

Orbital imaging serves three distinct purposes: (1) to confirm that the signs and symptoms are due to an orbital tumour; (2) to identify the nature of the tumour, its malignant potential, tissue type and extension into



(a) (b) (c) (d)

Figure 40.2 (a) Clinical photograph of a patient with squamous cell carcinoma (SCC) of the ethmoids with extension into the left orbital cavity. The tumour produces marked proptosis to the left eye with outer displacement and 'freezing' of the eye due to extensive infiltration of the occulomotor muscles. (b) The MRI (T2 weighting) shows the extension of the tumour of the anterior ethmoids and the nasal cavity into the orbit. There is direct invasion of the globe by the tumour which is confined into the anteriolateral compartment of the orbit. (c) Coronal plane of the MRI (T1 weighting). The tumour mass is depicted invading the orbit having destroyed the inner lateral thin bony wall. (d) Coronal plane of the MRI (T2 weighting). The tumour is confined in the naso-ethmoidal area with extension into the orbit without invading the base of the skull and the anterior cranial fossa.

(a) (b)

Figure 40.3 (a) Clinical photograph of a patient with orbital extension of a uveal melanoma. The intra-ocular extension of the tumour produces proptosis and conjunctival ecchemosis. (b) MRI (T2 weighting) showing the distraction of intra-ocular architecture of the globe by an ill-defined mass with irregular periphery and a mixed consistency. The lesion does not invade the peri-orbita.

other neighbouring tissues and (3) to monitor treatment effectiveness and the early identification of recurrence.

The main radiographic modalities used in orbital imaging are computed tomography (CT), magnetic resonance imaging (MRI), ultrasonography, positron emission tomography, digital angiography and radio nuclear scintigraphy.

Digital angiography should be considered for any patient with pulsatile exophthalmos.

HISTOPATHOLOGICAL DIAGNOSIS OF ORBITAL TUMOURS

Orbital biopsy techniques include excisional, incisional, core and aspiration biopsies and intra-operative biopsy with frozen section and Moh's methods. Sentinel node biopsy is also utilized occasionally for staging purposes of certain tumours.

SURGICAL TECHNIQUES

Enucleation is removal of the globe alone, whereas orbital exenteration refers to enucleation combined with removal of the entire orbital contents, including the globe, optic nerve, extra-ocular muscles, lacrimal gland and lacrimal drainage system, as well as the orbital fibroconnective and adipose tissues.

Individualization of exenteration cases should take into account the location, size and aggressiveness of the pathology, as well as the reconstruction plan. If the bones of the orbit are involved with malignancy, bone resection should be performed at the time of initial orbitotomy, even if that procedure is not an exenteration. Orbital exenteration may be subtotal, total and extended.

SUBTOTAL ORBITAL EXENTERATION

In eyelid-sparing exenteration, one may need to spare either the entire eyelid structure or just the eyelid skin. If the eyelid skin is to be spared, the skin incision is placed approximately 2–3 mm above and beyond the lash lines. The skin is dissected until the orbital rim is reached, then the periosteum is cut 360° 2 mm beyond the orbital rim, to continue the exenteration. If the entire eyelid anatomy is to be preserved, the operation is similar to an extended enucleation in which the eye with the bulbar conjunctival lining and the other orbital tissues are removed en bloc (Figure 40.4).

TOTAL ORBITAL EXENTERATION

In total orbital exenteration, the eyelids are closed with silk sutures. The bony landmarks are palpated and the line of the desired incision marked out. A circumferential skin incision is made overlying the orbital rim (Figure 40.5a). Unless the

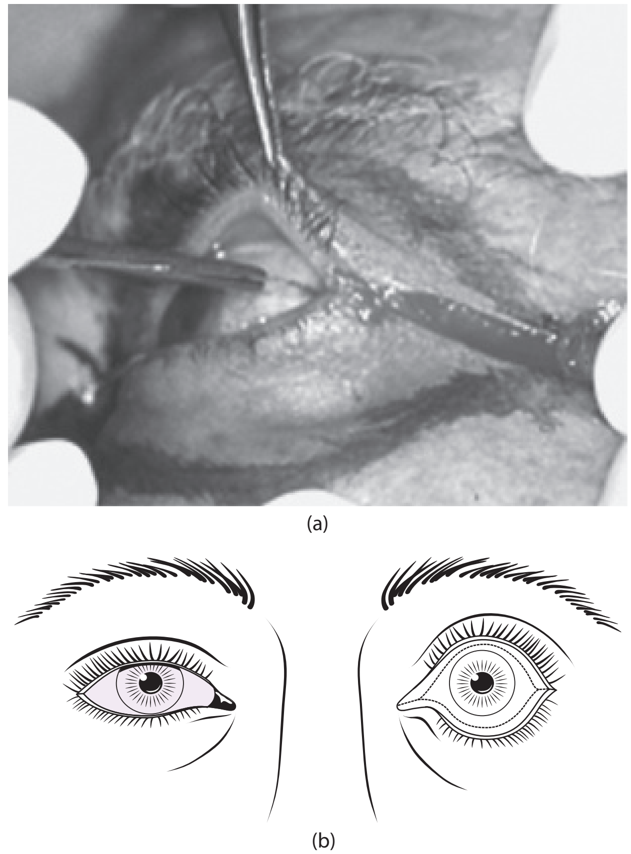


Figure 40.4 Schematic representation of the eyelid-sparing incision for subtotal orbital exenteration. (a) Lateral view. (b) Front view.

extent of the disease makes it necessary to do, otherwise the line of the incision lies just inside the orbital rim. Medially, it lies on the anterior lacrimal crest and laterally, it passes close to the outer canthus. On the nasal wall of the orbit, the periosteum must be raised gently, because the orbital plate of the ethmoid is very fragile and a sinus may result if the ethmoid air cells are opened. When the underlying soft tissues have been reached the incision is continued, usually with the use of unipolar cautery with a fine needle tip (a Colorado tip). To minimize bleeding, an incision is made in the upper quadrant, at the 12 o'clock position, which then proceeds clockwise, leaving dissection of the vascular nasal quadrant to the end. The peri-orbita is best incised a few millimetres outside the orbit, rather than on the orbital margin, as the blade of the knife can then be used perpendicularly to the bone (Figure 40.5b). Although the peri-orbita here is firmly adherent to the bone, it is thick and does not tear when raised. It is elevated with a sharp periosteal elevator (Figure 40.5c). When the periosteum of the orbital rim is reached, it is elevated and the dissection is swiftly continued beyond the rim into the orbit, to complete the procedure as quickly as possible (Figure 40.5d). In the region of the anterior lacrimal crest, the lacrimal sac is reflected laterally with the orbital contents when the periosteum is separated from the nasal wall. The nasolacrymal duct is identified as the dissection proceeds from the nasal wall to the floor

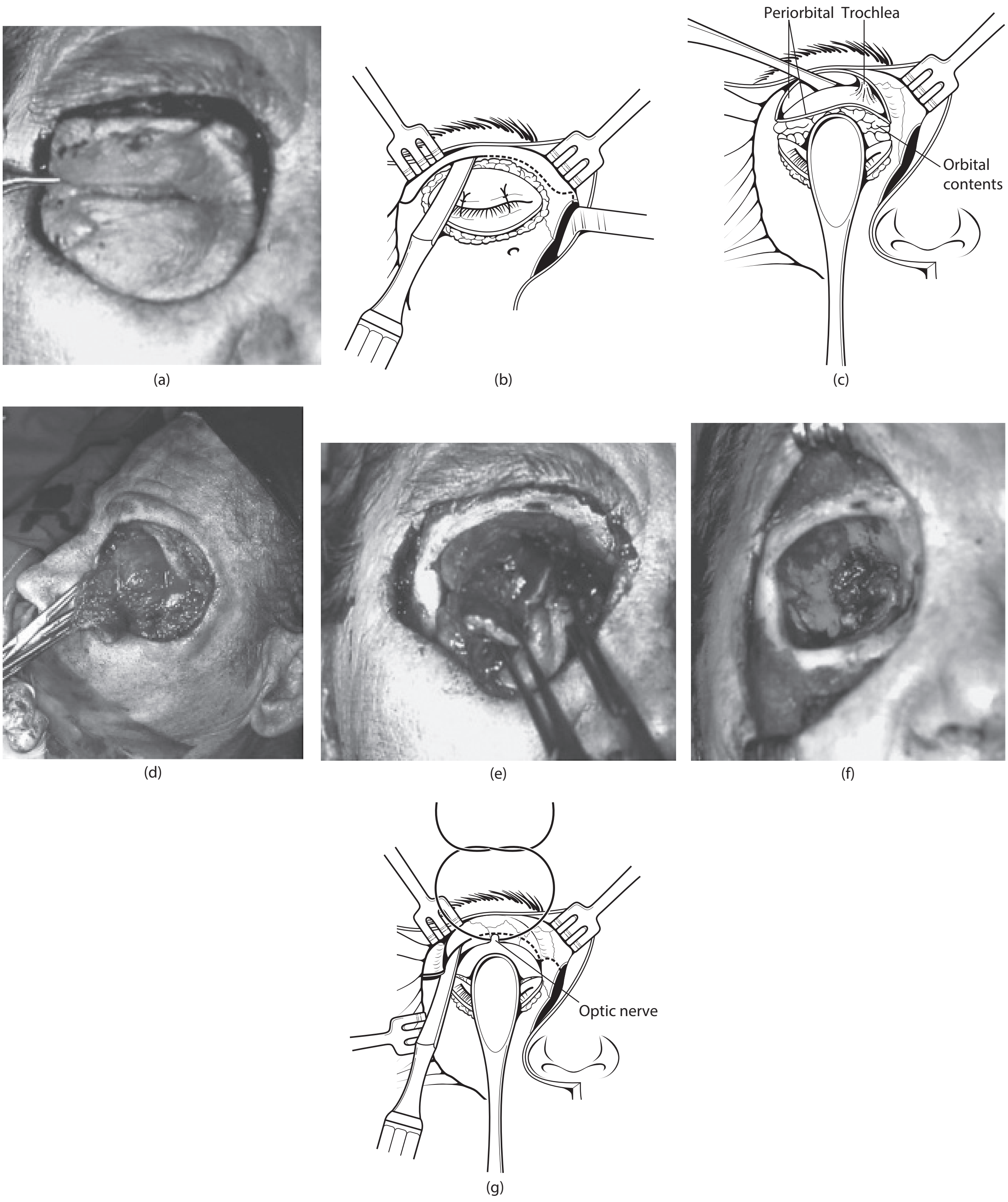


Figure 40.5 Schematic representation of total orbital exenteration in stages (see text for explanation of panels [a through g]).

of the orbit. Ligation of the duct prevents ascending infection from the nose and prevents blood running down into the nasopharynx. During dissection, bleeding is ignored unless haemorrhage is so profuse that it interferes with the view of the surgical field. Laterally, the temporal and malar branches of the lacrimal artery enter the malar bone and medially, the anterior ethmoidal artery passes from the orbit into the anterior ethmoidal foramen. These vessels are exposed and are clamped and coagulated with diathermy to avoid bleeding in the depths of the wound. When the soft-tissue dissection is complete, haemostasis with cautery is achieved (Figure 40.5e). When the dissection towards the

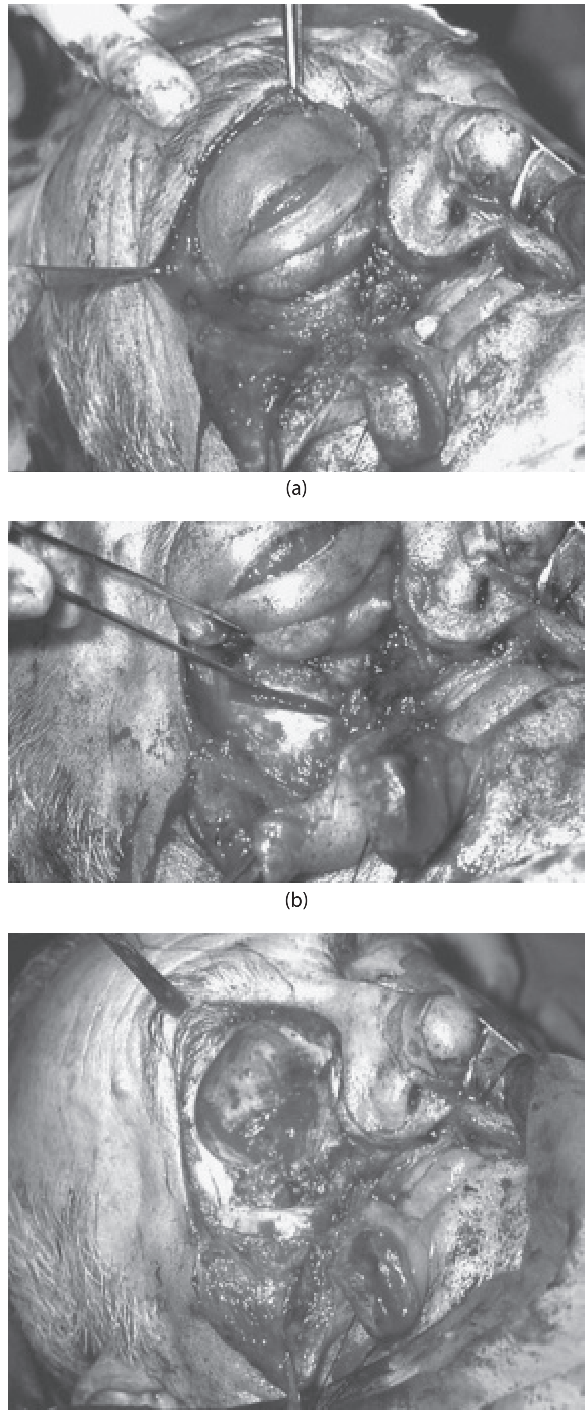
apex is completed, the apical bundle of soft tissues, including extra-ocular muscles, blood vessels and nerves, is reached. These tissues cannot be clamped or cut with one move. The bundle is approached from its nasal aspect, a strong curved haemostat is placed and the pedicle is cut with unipolar cautery or a curved pair of scissors above the haemostat. The same manoeuvre is repeated laterally and inferiorly to free the apex from orbital soft tissues. The bleeding sources of the apex (ophthalmic artery and vein) should be identified, clamped and tied after the removal of the bulk of the soft tissues (Figure 40.5f). Excessive application of electrocautery at the apex may create damage in the proximal portion of the optic nerve, which may extend into the optic chiasma. During orbital exenteration, most of the bleeding originates from the supraorbital and infraorbital vessels, the anterior and posterior ethmoidal arteries and the ophthalmic artery when the dissection reaches the apex. Although the posterior bleeding is the most significant, it is easier to control, since by the time the apex of the orbit is reached, all soft tissues have been freed and there is better visibility (Figure 40.5g). After removal of the orbital contents, it may be possible to apply clamps behind those previously used to reduce the size of the stump by the removal of more tissue. The pedicle is transfixed and ligated.

EXTENDED EXENTERATION WITH RESECTION OF THE OSSEOUS ORBIT

After total orbital exenteration, the orbital walls are examined for any evidence of neoplastic involvement. If there is any diseased bone it is then chiselled away, cutting through healthy bone. There are no standard techniques for bone resection. In most cases, removal depends on the extent and location of the bony invasion. In most areas of the orbit, it is preferable to score the bone with an oscillating saw along the predetermined limits of resection and then fracture the bone en bloc with a strong rongeur. In some sites, a sharp osteotome and a mallet may be needed to remove pathologic bone (Figure 40.6).

EXTENDED EXENTERATION WITH RESECTION OF THE PARANASAL SINUSES

Extensive primary paranasal and skull base malignancies can infiltrate the orbital content. There are four grades of orbital involvement through the paranasal sinuses: (1) tumour adjacent to the orbit, without infiltration of the orbital wall; (2) tumour eroding the orbital wall without ocular bulb displacement; (3) tumour eroding and infiltrating the orbital wall, displacing the orbital content, without peri-orbital involvement; (4) tumour invading the orbit with peri-orbital invasion. In cases of obvious bony orbital tumour involvement, the orbit with the adjacent bone and sinuses should be removed. The conventional treatment of the sinonasal malignancies with orbital extension is maxillectomy with orbital exenteration. This



(a) (b) (c)

Figure 40.6 Extended orbital exenteration with resection of the osseous orbit. (a) Incision lines resemble those of the total orbital exenteration. If needed a lateral rhinotomy extension is performed to facilitate resection of the orbital floor. (b) An osteotomy is performed to include parts of the lateral orbital wall and the bony floor of the orbit. (c) The surgical bed after the extended orbital exenteration.

extended hemi-maxillectomy is approached through a Weber–Fergusson–Dieffenbach skin incision (Figures 40.7 and 40.8). Ethmoidal malignancies invade the orbit in over 80% of cases. The anatomy of the area and the

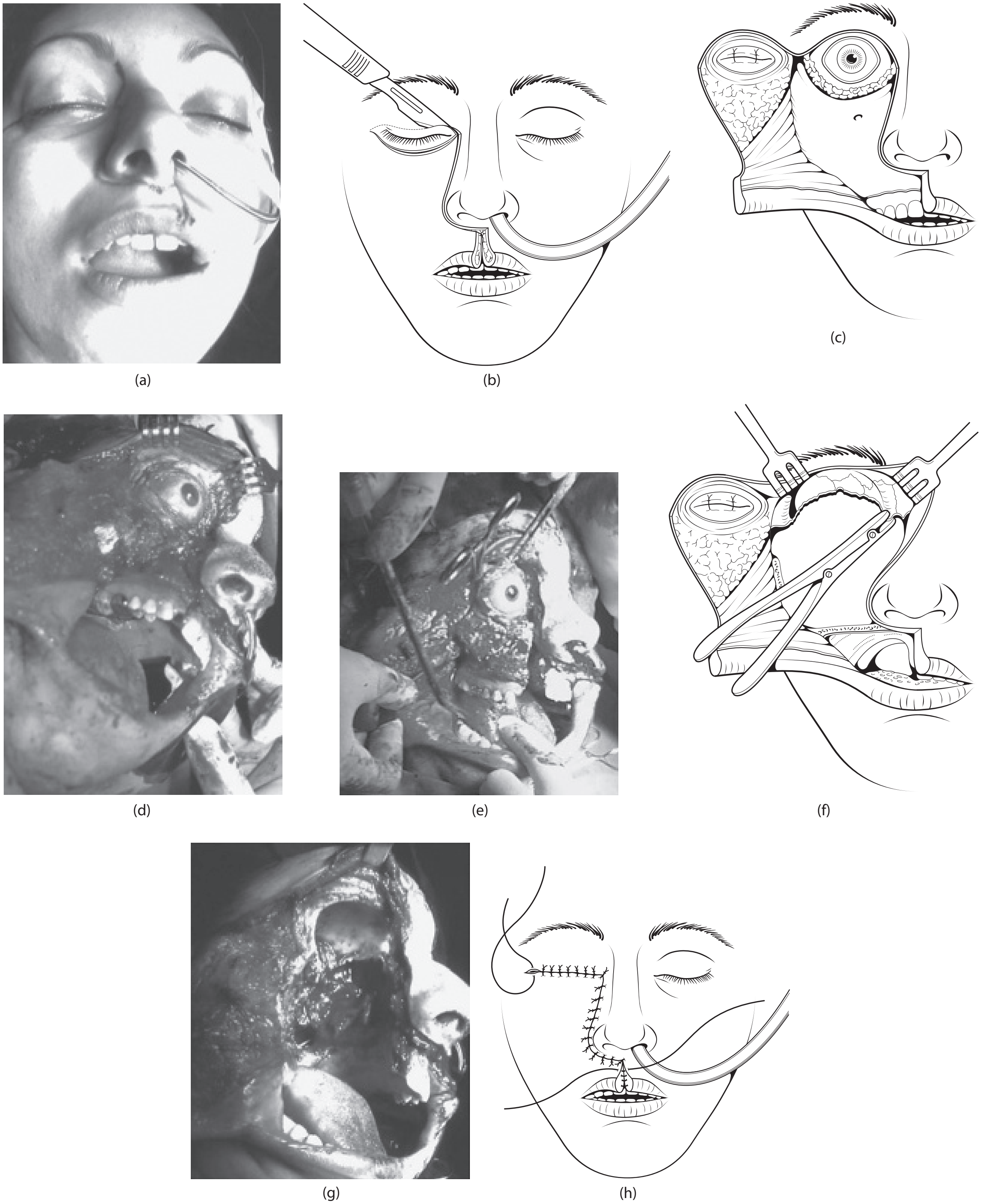
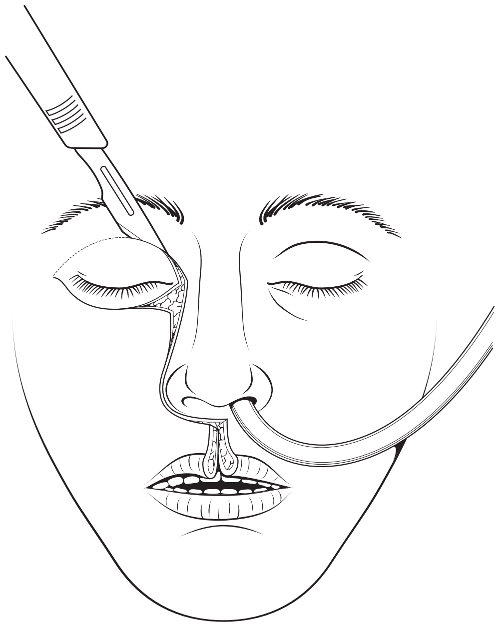
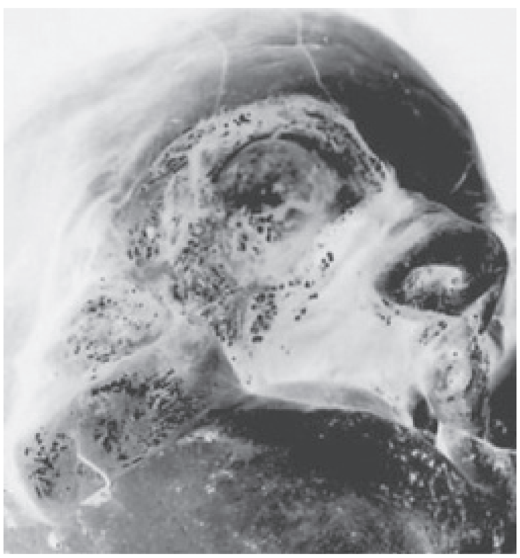


Figure 40.7 Schematic representation of extended orbital exenteration with resection of the paranasal sinuses. (a and b) The incision line when a lid-sparing procedure is favoured. (c and d) The cheek flap is reflected and the anterior and lateral walls of the maxillary sinus and the orbit are visualized. (e) Osteotomies are performed to separate the lateral middle third of the face from the facial skeleton. Transection of the zygomatic arch and bone are necessary for the mobilization of the osseous part of the skeleton containing the tumour. (f and g) After the resection of the specimen additional fragments of the facial skeleton may be necessary to be removed. (h) The skin closure lines.



(a)



(b)

Figure 40.8 (a) Schematic representation of extended orbital exenteration with resection of the paranasal sinuses when the lids must be resected with the tumour. (b) The surgical defect after tumour resection.

separation of the orbital cavity from the ethmoids by the lamina papyracea favours the invasion of tumour into the orbit (see also Chapter 39).

RECONSTRUCTION

An essential part of the decision-making process is reconstruction and rehabilitation of the exenterated orbital socket. A decision should be made pre-operatively whether the patient will wear a patch or a prosthesis.

Primary surgical closure of the orbital cavity is advantageous with respect to both function and aesthetic outcome, and makes early post-operative radiotherapy possible. With CT and MRI, early local recurrence can be identified.

Orbital exenteration results in significant deformity. The primary goal of reconstruction is the restoration of boundaries between the orbit and surrounding cavities and an acceptable aesthetic outcome.

Orbital reconstructive techniques can be divided in three groups: (1) local reconstructive options (healing by secondary intention, split skin graft or dermis–fat graft), (2) regional reconstructive options (temporalis muscle transfer, frontalis rotational flap or a variant of these procedures) and (3) distant reconstructive options (pedicle musculocutaneous flaps or free vascularized flaps).

Local reconstructive options

Spontaneous granulation

The simplest approach is to pack the orbit with iodine impregnated gauze and allow the socket to granulate. When the eyelids are entirely removed, the free skin margin is tacked to the orbital rim with interrupted silk sutures and the socket is lined with antibiotic-soaked Vaseline or Xeroform gauze.

Healing may take 8–10 weeks. By the time granulation is complete, the orbit is covered with a very thin epithelium, which has the advantage of allowing the visual detection of recurrent tumour at an early stage. The resulting cavity is deep, but can be fitted with a silicone oculofacial prosthesis. The need for regular dressing changes must be weighed against the potential benefits of healing by secondary intention.

Significant numbers of patients develop sino-orbital fistulas from perforation of the sinuses occurring pre-operatively (Figure 40.9).

Eyelid-sparing technique

Because the eyelids and conjunctiva are supplied by an extensive vascular network, these tissues remain viable after loss of the posterior orbital circulation. Eyelid-sparing, subtotal exenteration offers significant advantages in terms of reconstruction of the orbit and cosmesis. When it is consistent with the complete removal of all malignant disease, the lids are preserved, and either turned into the cavity as a lining or used to retain a prosthesis (Figure 40.10).

Free skin grafting

The socket may be lined on completion of the exenteration with a split-thickness skin graft. There are a number of advantages for this technique. It is a technically simple procedure which takes little time and it provides a socket that is easily accessible for clinical examination. While split skin grafts provide a reliable lining, they take time to heal and stabilize.

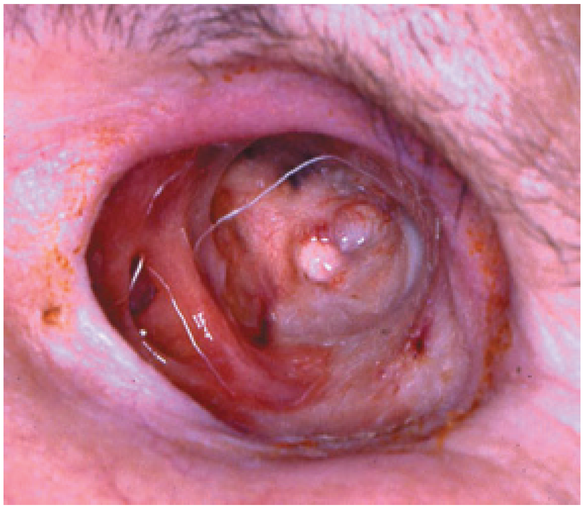


Figure 40.9 Clinical photograph of a left exenterated orbit after spontaneous granulation. The stub of the optic nerve with its adjacent vessels can be seen. A sino-orbital fistula has been created resulting in an orbito-ethmoidal communication.

Figure 40.10 Clinical photograph of a left exenterated orbit with lid-sparing technique.

The graft must be free of hair follicles. A graft measuring 8 cm at its widest point is sufficient to line the orbital cavity and a graft of this size can be obtained from the anterior thigh. When the skin graft has been inserted into the orbit, it is important to ensure close approximation of the graft to the bony wall. It is sutured to the margins of the skin with interrupted absorbable sutures, and the orbit is packed with Xeroform gauze as a mould to provide firm apposition of the graft to the bone. Success depends on the entire surface being held in contact with the bone by firm even pressure.

Although orbits lined by skin grafts heal faster than ungrafted ones, they do not have the advantage of developing fibrosis (Figure 40.11).

Regional reconstructive options

Median forehead flaps

Because forehead flaps are designed with an intact major blood vessel, they provide healing and do not require

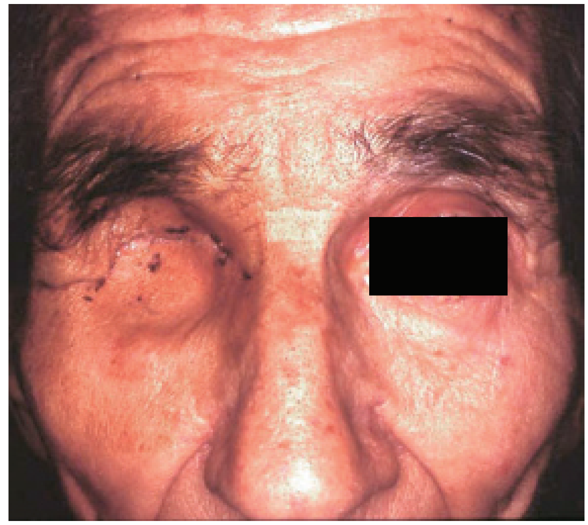


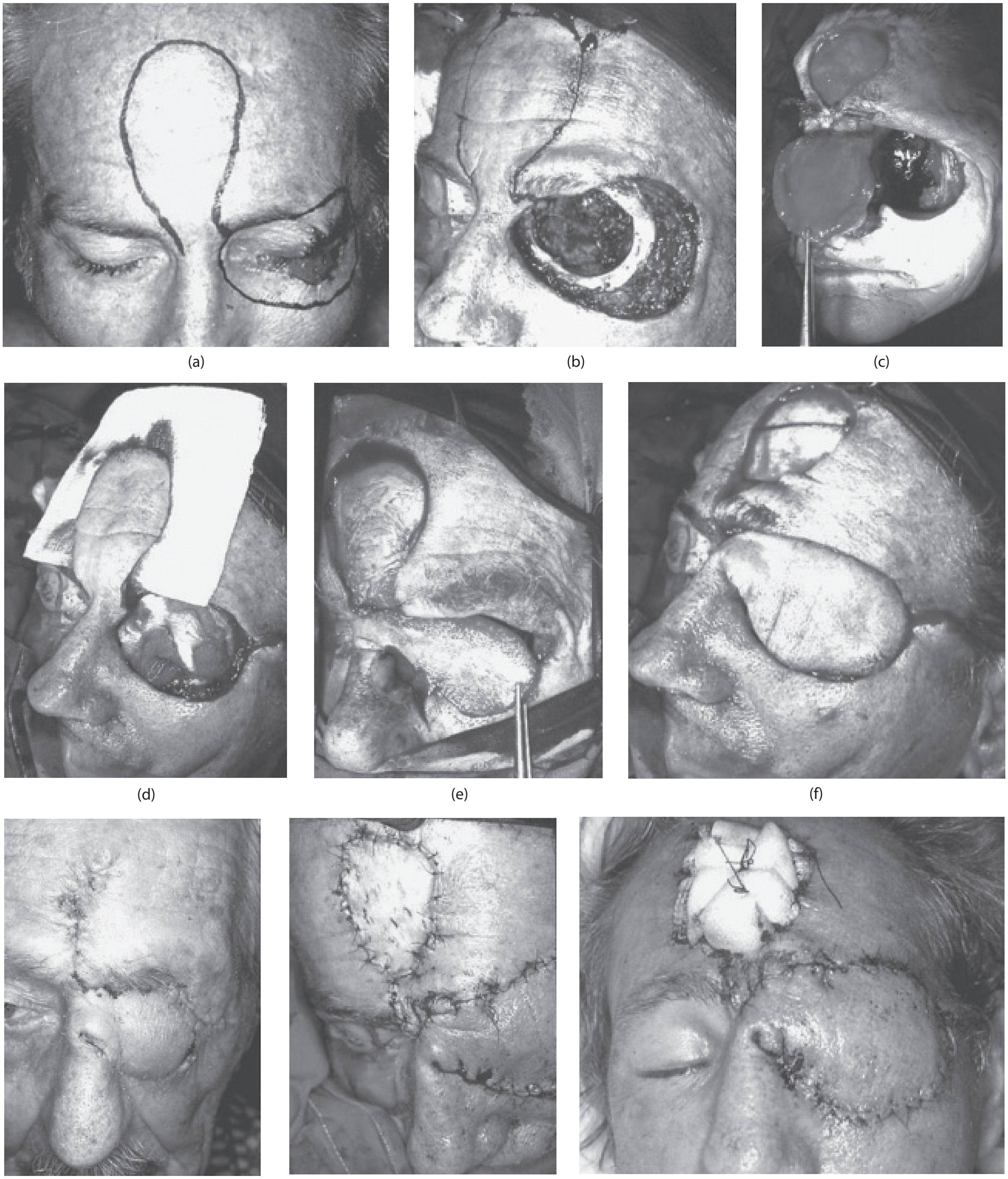
Figure 40.11 Clinical photograph of a right exenterated orbit lined with split thickness skin graft.

specialized microvascular surgery. Forehead flaps provide ample tissue for the repair of nasal and maxillary defects that often accompany the resection of orbital and periorbital tumours.

The forehead flap results in aesthetic morbidity at the donor site, a common complaint of patients who undergo such procedures.

Surgical technique

The median forehead flap is outlined on the skin (Figure 40.12a). An incision in the natural horizontal furrow of the forehead or parallel to it is made down to the frontal bone periosteum (Figure 40.12b). The flap is dissected from its apex towards the base. The subdermal dissection is performed with care taken to leave subdermal vascular territory to maintain the blood supply of the remaining skin, and also with care taken to leave sufficient tissue, including muscle, at the level of the brow to fit the bulk of the flap and to protect hair follicles (Figure 40.12c). When the subperiosteal dissection is made towards the level of the orbital rim, the supratrochlear and supraorbital vascular pedicles and supraorbital nerve should be identified. After that, the base of the flap can be undermined sufficiently to permit its easy adaptation (Figure 40.12d). Based on its pedicle, the flap is rotated 90°, with a rotation point at the level of the orbital rim (Figure 40.12e). After the flap is adapted as a turnover to the defect, it is sutured to the edges of the skin of the orbital defect with 5/0 Vicryl sutures (Figure 40.12f). The defect in the forehead, depending on the size of the elevated median forehead flap, is either primarily sutured or can be covered with a full-thickness free skin graft (Figure 40.12g). The grafted full thickness skin can be harvested from the supraclavical area or when in the form of a split-thickness skin graft can be taken from the thigh. A tie-over dressing is applied and is left in place for 10 days (Figure 40.12h and i). The entire middle third of the forehead will survive elevation on the



(a) (b) (c) (d) (e) (f) (g) (h) (i)

Figure 40.12 Schematic representation of the use of median forehead flap to cover a total exenteration surgical defect [see text for explanation of panels (a) through (i)].

basis of the dominant vascular pedicle and its height can reach the hairline. The 90° twist needed to reach the exenterated orbital cavity does not usually impair the blood supply. A potential complication is transfer of eyebrow hair to the socket.

From a functional and an aesthetic standpoint, the median forehead flap is an excellent choice for small- or medium-sized orbital defects. The forehead skin more closely matches the pigmentation and structure of the periocular tissue. Forehead flaps can be used in conjunction

with other local and regional flaps to repair larger orbitofacial defects. The relative ease of harvesting the flap minimizes operative time and the robust blood supply decreases failure rates (Figures 40.13 and 40.14).

Temporalis fascia and muscle flaps

Among the advantages of the temporalis muscle flap (TMF), one can include easy surgical technique, reliability of the vascular pedicle, sufficient volume to cover large surgical defects, versatility in its application, minimal post-operative complications and freedom from dysfunction at the donor site.

The TMF is one of the most frequently used flaps to obliterate the orbital cavity, but only a small portion of the muscle can be used unless additional procedures, such as fenestration of the lateral orbital wall or resection of the lateral orbital rim, are performed. Even these procedures do not enable the entire mass of the muscle to be used, because most of the muscle bulk acts as the pedicle.

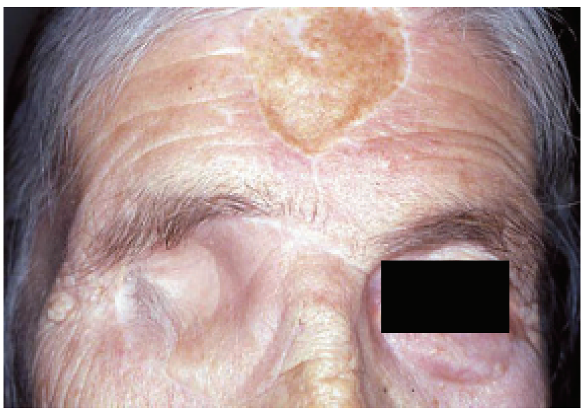


Figure 40.13 Clinical photograph of a female patient with a right total orbital exenteration and a median forehead flap to reconstruct the orbital defect.

Figure 40.14 Clinical photograph of a male patient with a right total orbital exenteration reconstructed with a median forehead flap.

The temporoparietal fascial flap (TPFF) is the only fascial flap that can be harvested as a pedicled flap for peri-orbital and socket reconstruction. Its thin width (average width 2–3 mm) and need for grafting are the main disadvantages.

Small paranasal sinus or brain fistulas are obliterated by performing locoregional flaps transposed through the lateral orbital wall. In more extensive cases, the boundaries between the empty orbit and adjacent cavities must be re-established with free tissue transfer. A common procedure is to borrow a portion of the temporalis muscle from its anterior half, pass it through the lateral wall, and fill the orbital cavity with the bulk of this graft. Skin graft can be placed over the muscle flap. In most instances, this procedure effectively makes the exenteration cavity shallow.

Distant reconstructive options

Pedicled flaps

Regional flaps are used frequently for reconstruction following exenteration, but these flaps can cover only the anterior orbit and leave potential dead space posteriorly.

Use of the pectoralis major myocutaneous flap for orbital reconstruction is limited, due to the distance the muscle pedicle has to travel from the anterior thoracic wall to the orbit. There have been attempts to use the sternocleidomastoid, trapezius, latissimus dorsi and platysma flap.

Other local flaps like the cheek flap, the submental and the retroauricular island flap can also be used to reconstruct peri-orbital defects. They provide superior cosmetic results through enhanced matching of skin colour, texture and structural characteristics, have a rich vascular supply and a low complication rate, and do not require complex microvascular surgery.

Microvascular free flaps

Surgical reconstruction of the orbital cavity after orbital exenteration with maxillectomy is technically challenging. The reconstruction of such defects obliterates any communication between the orbit and the nasopharynx, reconstructs the palatal surface and the nasal airway, and provides an acceptable cosmetic result. Ideally, the selected tissue should facilitate this and provide a well-vascularized bed to withstand post-operative radiotherapy.

Microvascular free flaps have also been used to cover defects following extended orbital exenteration. Facial or temporal vessels may be suitable for microvascular anastomoses. A wide selection of free flaps can be used in orbital and orbitomaxillary defects.

Primary reconstruction of orbit and maxillary defects with free microvascular rectus abdominis flaps has numerous advantages. In contrast with procedures that use the temporalis or the pectoralis major as a pedicled flap, the rectus abdominis free flap permits reconstruction

with larger volumes of well-vascularized tissue and greater flexibility in placement without associated orientation problems.

Maintaining the nasal airways is often the most difficult problem in this particular group of patients, and a second skin island to address lateral nasal wall reconstruction is often helpful (Figure 40.15).

Ocular and oculofacial prosthetics

Orbital prosthetics are never completely lifelike, because vital eye movements are absent. Spectacles can camouflage this aesthetic deficiency and protect the uninvolved eye at the same time.

The key decision to be made when approaching an orbital exenteration defect is whether to leave the cavity open or closed. An open cavity requires less sophisticated surgery, may permit better tumour surveillance and allows the use of a prosthesis. However, an open cavity can lead to surrounding tissue contracture with inferior displacement of the brow and distortion of the cheek.

Despite recent advances in contemporary oculofacial prosthetics, the aesthetic results after a standard orbital exenteration remain poor and unacceptable for many patients. Although traditional exenteration with a spectacle mounted, osseointegrated or adhesive-secured prosthesis may achieve acceptable cosmesis, many patients have difficulty in obtaining good prosthetic support. Many patients prefer to wear an eye patch to cover the surgical site.

The basic requirements for an exenterated socket that can maintain an ocular prosthesis are (1) orbital tissue volume to support the prosthesis, (2) a mucous membrane surface with fornices to accommodate the prosthesis and (3) eyelids to hold the prosthesis within the socket. The limiting factor in most exenteration cases is the preservation of a mucosal surface, which is essential if the prosthetic shell is to be comfortable. Unless significant portions of the conjunctiva can be retained, an ocular prosthesis is not a rehabilitative option after orbital exenteration, and the surgical plan should take this into account.

Osseointegrated implants have helped overcome a number of the problems associated with facial prostheses. They provide reliable anchorage for large and heavy prostheses and facilitate their rapid placement and removal. Modern magnetic capped implants are very simple to use.

COMPLICATIONS

The most serious post-operative complication in orbital surgery is haemorrhage, which can happen immediately post-operatively or weeks later, but generally occurs in the 4–6 days after the operation. Because the orbit is small and closed, any haematoma may be significant. Wound infection and dehiscence, as well as orbital cellulitis, are unusual postoperative complications following tumour resection.

Orbital exenteration defects left to granulate spontaneously can be complicated by a prolonged healing phase, chronic hygiene problems, orbitosinus or orbitonasal fistula formation, dural exposure and cerebrospinal fluid leaks. The high rate of sino-orbital fistulas following spontaneous granulation of exenterated orbital cavities can be avoided by formal surgical closure and reconstruction.

(a) (b)

Figure 40.15 (a) Clinical photograph of a patient with extensive basal cell carcinoma (BCC) of the eyelids which extends to the peri-orbital skin tissues. (b) The extended orbital exenteration defect has been reconstructed with the use of a rectus abdominis muscle free flap covered with split thickness skin graft.

Top tips

- Use MRI for the delineation of the orbital tumour.
- Use CT for the identification of osseous extensions of the orbital mass.
- Use unipolar cautery (Colorado tip) to delineate the orbital incision.
- Use periosteal elevator to dissect the peri-orbita from the orbital walls.
- Use curved scissors to cut the optic nerve, and ophthalmic artery and vein.
- Ligate the ophthalmic vessels.
- Start the reconstruction after the extirpation of the tumour as you may need to change the reconstructive plan according to intra-operative findings.

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41

Neck dissection

PETER A BRENNAN and MARK SINGH

CONTENTS

INTRODUCTION

Many of the surgical principles described in this chapter have not changed significantly since 1906 when Crile published his classic paper describing 132 neck dissections (36 radical and 96 more selective procedures). Only 2 years later, Sir Henry Butlin described a procedure that is essentially the same as a current supra-omohyoid neck dissection (SOHND). Despite this publication of a 'selective' neck dissection, most elective treatment of even the clinically negative (N0) neck during the first half of the 20th century consisted mainly of radical neck dissection (RND). Over the last 20 years, there has been an increasing trend towards selective neck dissection (SND) for the initial management of patients with no clinical evidence of neck metastasis, and in carefully selected patients with nodal metastasis (although its use in the latter remains controversial).

Whilst SND preserves many vital structures (such as the accessory nerve), the functional results after these procedures are not as good as expected. Shoulder function and pain scores are worse in patients who undergo posterior triangle dissection, which may not recover despite preservation of the accessory nerve. A study has found that the variables that contribute most to quality of life scores relating to the neck were age and weight, radiotherapy to the neck and type of neck dissection.

NECK DISSECTION CLASSIFICATION

Neck dissection nomenclature can be confusing. It can be simplified as follows:

- *Radical neck dissection.* This refers to removal of lymph nodes in levels I–V en bloc with the sternomastoid muscle, also known as sternocleidomastoid muscle (SCM), internal jugular vein (IJV) and spinal accessory nerve. This operation is both cosmetically and functionally mutilating and is used in gross metastatic disease, involving multiple levels of the neck and when preservation of the above structures would compromise surgical clearance. Although this operation has been regarded as the 'gold standard' for the surgical treatment of metastatic neck disease, it has largely been replaced by more selective surgery.
- *Modified radical neck dissection* (MRND) refers to dissection of levels I–V but with the preservation of one or more of the following structures: IJV, spinal accessory nerve and sternomastoid. The nomenclature refers to the number of structures preserved (so MRND type I is preservation of one of these structures, MRND type II is preservation of two structures and so on). Both RND and MRND are used when the neck has evidence of nodal metastasis (N+), although there is growing evidence to suggest that the more SND (see below) has a role to play not only in staging but in the management of the N+ neck as well. The reader is referred to an excellent recent review of this subject by Ferlito et al.

- *Selective neck dissection*. In 1991, the Committee for Head and Neck Surgery and Oncology of the American Academy of Otolaryngology and Head and Neck Surgery indicated that 'in all SND, the IJV, spinal accessory nerve and SCM are routinely preserved. If removal of one or more of these structures is necessary, the structure should be listed after the appropriate term for the neck dissection'.[1] As a result, SND can easily be confused with MRND and indeed some surgeons use the terms interchangeably. However, SND should refer to the dissection of one or more levels of the neck (with careful preservation of the anatomical structures listed above, as well as other nerves such as the marginal mandibular branch of the facial nerve) rather than all five levels. Examples include the SOHND, (levels I–III), lateral compartment neck dissection (levels II–IV) and levels I–IV neck dissection.

TERMINOLOGY OF NECK LEVELS

The most significant change to the well-known Robbins classification was the publication of an updated system in 2002. In addition to the five standard levels, nodal levels were subdivided into levels IA and B, IIA and B (below and above the accessory nerve) and VA and B (above and below the accessory nerve in the posterior triangle) (Figure 41.1). The concept of sublevels is clinically relevant since metastasis to level IIB from anterior oral cavity tumours is uncommon and metastases to level VA is rarer still, with studies advocating that the dissection of these levels is not usually necessary.

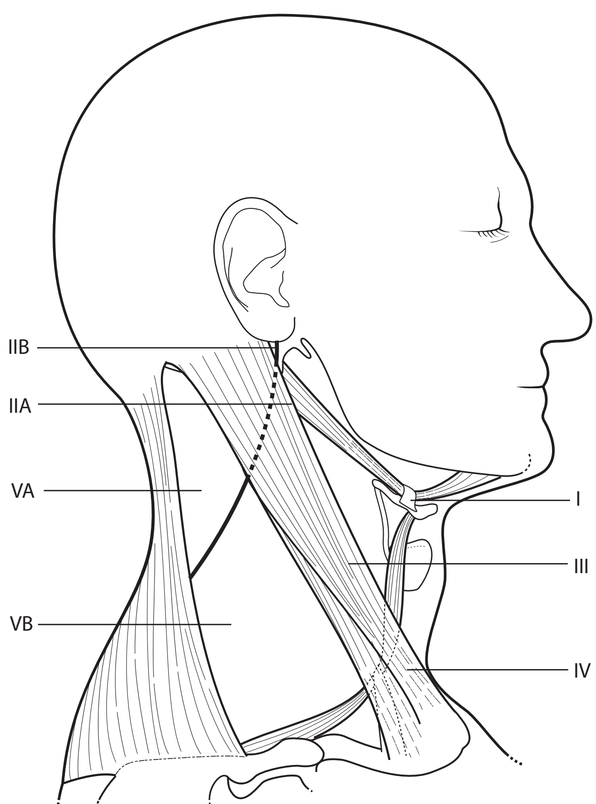

Figure 41.1 Levels of the neck. Level is divided into 1A (submental) and IB (submandibular triangles).

PRINCIPLES OF SURGERY

The rationale for neck dissection is based on predictable patterns of lymphatic spread from the primary tumour site, and the relative risk of nodal metastatic disease. Over 30 years ago, Lindberg's clinical study found that the jugulo-digastric and mid-cervical nodes (levels II and III) were the most frequently involved in metastatic disease from the oral cavity. Tumours of the lip, anterior two-thirds of the tongue, floor of mouth and buccal mucosa also metastasize to the level I nodes (submental and submandibular triangles), often bilaterally. Lindberg described the possibility of skip metastasis, avoiding the first echelon nodes and spreading directly to the level III area. More recent studies have found that when levels I–IV are negative and level V is never node positive, supporting the use of the SND for the N0 neck. Despite many published studies, there is still controversy about neck dissection surgery and the reader should refer to specialist textbooks for a full discussion.

When taking trainees through a neck dissection, the author makes the analogy of walking through a jungle. Some structures in the neck (such as the digastric and omohyoid muscles) will help to delineate the path – these are your trusted guides. However, you will also come across many dangers, which if not treated with respect could take you by surprise, sometimes when you least expect it! These include structures such as the phrenic, hypoglossal and marginal mandibular nerves.

TECHNIQUE

1. *Patient position*. For all neck dissections, the fully anaesthetized (but unparalysed) patient should be placed supine on the operating table with the head turned away from the side being operated. A sandbag can be used if required to elevate the shoulder. It is sensible to expose the neck from the sternum and lateral clavicle to the ear and lips. Following skin preparation, the drapes need to be secured in place using adhesive strips, sutures or skin clips. It is useful to keep the lower lip exposed (to check for marginal mandibular nerve function).
2. *Choice of incision*. This depends on the type of neck dissection being undertaken. Ideally, skin incisions should be placed in natural skin creases, following Langer's lines. The lower border of the mandible, sternomastoid and clavicle can be marked to assist placement of the incision. For a SND, an incision running from the mastoid to submental area 3 cm below the mandible is usually adequate. When levels IV and V are being dissected, it may be necessary to place a

second incision to gain access to these areas. The author routinely uses a Schobinger-type incision for MRND (Figure 41.2), except in the previously irradiated neck, where a MacFee incision is preferred (to reduce the risk of wound dehiscence). When a Schobinger incision is used, it is important not to place the tri-radiate part of the incision over the great vessels, especially if the sternomastoid is removed (risk of wound infection and vascular compromise!). If a MacFee incision is used – this is the correct spelling of the author who described it in 1960[2] – some spell it McFee! – an adequate bridge of skin between the incisions (of at least 4 cm) is essential to minimize the risk of skin necrosis (Figure 41.3). It is important to mark either side of the incisions (using needle and Bonney's blue, or superficially scoring the skin with the back of a scalpel blade) to facilitate subsequent skin closure.

3. *Development of skin flaps.* It is usual to raise skin flaps in a subplatysmal plane. Local anaesthetic solution may be injected to facilitate this process. The flaps can be raised using monopolar diathermy (Colorado needle), scalpel or scissor dissection. With all of these techniques, but particularly when diathermy is used, care should be taken in the upper skin flap to minimize damage to the marginal mandibular nerve, which lies just deep to the platysma muscle in the deep cervical fascia. It can be readily identified as it crosses the facial vessels (FVs) and great care should be taken to preserve this nerve. It is sometimes possible to preserve the great auricular nerve as it crosses the SCM although the roots (C2,3) are often transacted later on in the dissection. In both the submental and posterior triangles, the platysma muscle often fades away and care should be taken to ensure that the skin flap does not become too thick or thin in these areas. It is sometimes surprising just how superficial the accessory nerve can be! The external jugular vein is easily damaged when the inferior skin flap is being raised as it lies immediately deep to the platysma muscle and may need to be ligated. The flaps should be developed beyond the boundaries of the neck dissection to be performed. For a MRND, the flap should be extended to the trapezius muscle in the posterior triangle. The muscle can be brought into view by having an assistant pushing it upwards and forwards. In bulky disease, it may be necessary to leave the platysma on the metastatic nodes, or even include skin in the resection if clinically indicated. In these cases, it is important to plan skin incisions to facilitate subsequent closure.

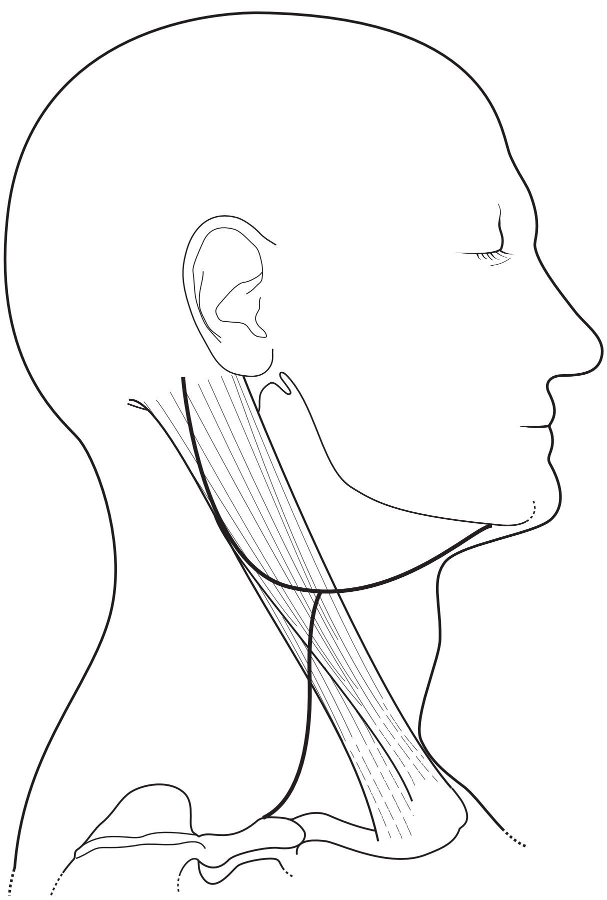

Figure 41.2 Schobinger incision for modified radical neck dissection (MRND).

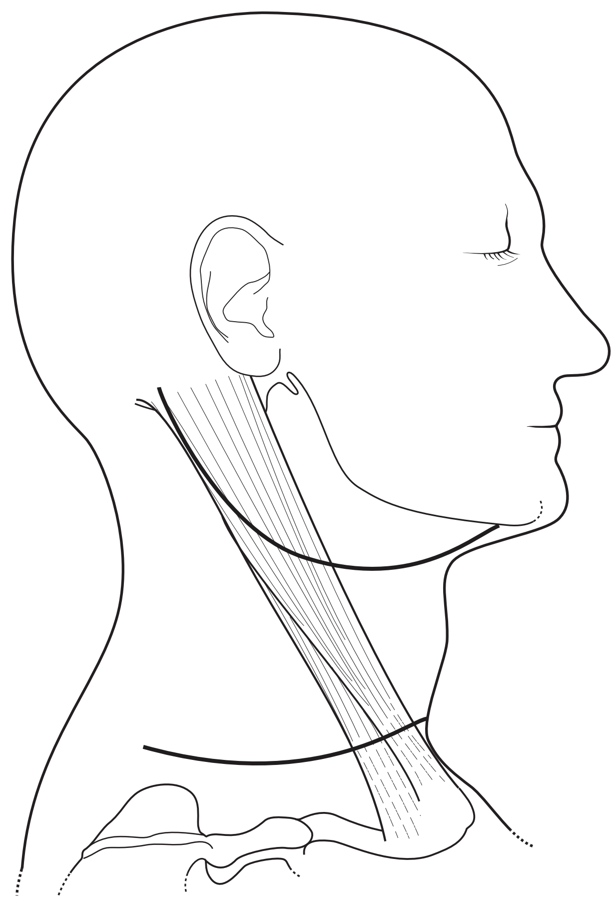

Figure 41.3 MacFee incision. Distance between incisions should be at least 4 cm.

4. *Start of neck dissection proper: I–IV SND.* Where should I start the neck dissection? This is a question often asked by newcomers to this procedure. There are many ways to perform the procedure (inferiorly to superiorly, posterior to anterior and so on) and it is often good to try different methods and to vary these on separate occasions to find a way that works for each operator. Even then, one's routine procedure may need to be modified when, for example, a large metastasis is present in level II, in which case it is often wise to start somewhere else. Also, if one particular area is proving difficult, move on to another region and come back to it. The procedure described below is for a level I–IV SND. The RND and MRND variations are discussed subsequently.
5. *Mobilization of the SCM.* The fascia overlying the SCM is incised along the whole posterior margin length of the muscle and lifted anteriorly. The dissection is continued close to the muscle in a broad front inferiorly and superiorly around its anterior border. Superiorly, the tail of the parotid and the posterior digastric muscle will come into view on its way to the mastoid process. The SCM is then retracted posteriorly, and the carotid sheath will come into view, initially with the IJV (Figure 41.4). By maintaining a broad front, the SCM can be skeletonized away from the underlying deep structures. It can then be retracted with vascular slings. The omohyoid muscle will be seen inferiorly, the tendon of which passes superficial to the IJV. This muscle arbitrarily divides the 'surgical neck' into levels III and IV, although the position of the muscle varies with neck position. For a level IV dissection, the omohyoid is dissected free from the IJV, whereas in a SOHND, the dissection commences superiorly to the upper border of this muscle. As one dissects superiorly, the accessory nerve will be found deep to the posterior digastric passing in a medial to lateral direction into the anterior border of the upper third of the SCM. It can often be felt as a cord like structure. By hugging the anterior border of the SCM in a broad front, this important nerve is easily identified. It is worth noting that this nerve has many anatomical variations (one can be seen in Figure 41.5), and it can pass superficial, deep or even through the IJV.
6. *Clearance down to pre-vertebral fascia.* The fatty tissue containing nodes posterior to the IJV is carefully incised at the inferior extent of the dissection in a horizontal direction. This is done in stages, so as to not inadvertently go through the thin pre-vertebral fascia. The use of scissor dissection combined with the intermittent use of a wet swab to sweep this tissue off the pre-vertebral fascia enables easy identification of this fascia. The phrenic nerve will be seen under the pre-vertebral fascia passing from lateral to medial on the scalenus anterior muscle (Figure 41.6). More laterally at the root of the neck, the upper trunks of the brachial plexus may also be visualized, again under the fascia.

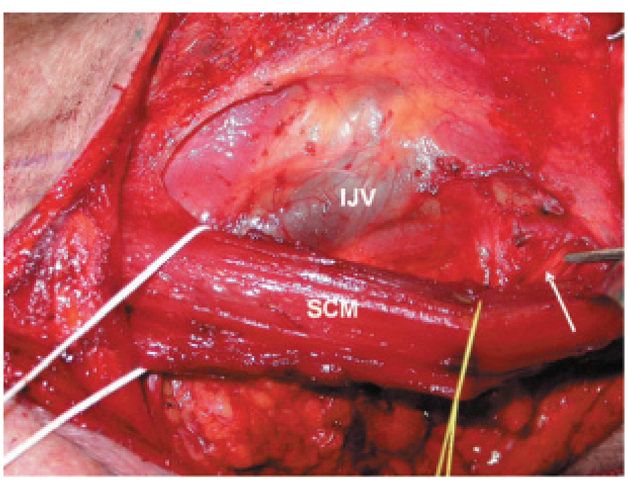

Figure 41.4 Dissection around sternomastoid muscle (SCM) to reveal internal jugular vein (IJV). The accessory nerve is just coming into view (arrowed).

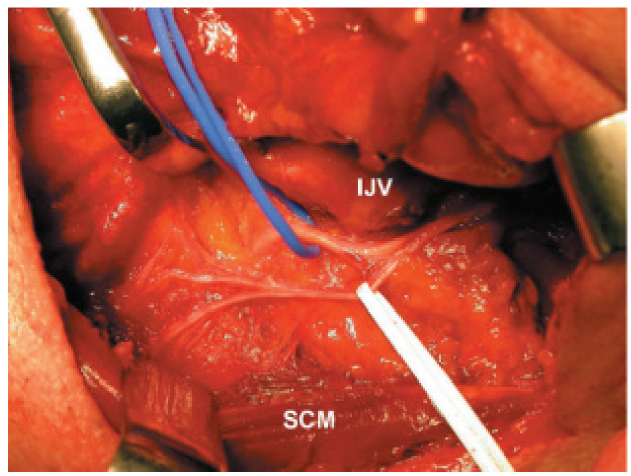

Figure 41.5 Identification of the accessory nerve. In this case, a variant with innervation from a cervical plexus nerve.

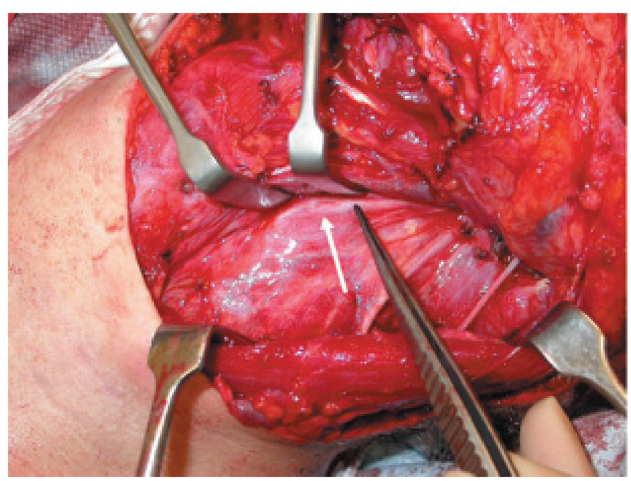

Figure 41.6 Clearance in level IV. The phrenic nerve under the pre-vertebral fascia is arrowed.

The author routinely extends this dissection laterally to the area over which lies the posterior border of the SCM (effectively including the anterior border of level V in the dissection). Once the correct depth has been established, it is quite easy to carry the postero-lateral part of this dissection in a superior direction. This can be facilitated by appropriate retraction and counter-traction. As the dissection proceeds in this way, one will come across cervical nerves that have pierced the pre-vertebral fascia. These can be cut as long as they are superficial to it and the phrenic nerve has been identified. In some cases it is possible to preserve some of these nerves, thereby maintaining sensation to the skin in the dermatomes supplied by them. As one reaches the accessory nerve superiorly, the sternomastoid is retracted fully, and the level IIB can be cleared down to the muscular floor. The anatomical variations of this nerve should be remembered (it can be anterior [most common] or posterior to the IJV, or even pass through the vein). Level IIB contains the occipital artery, which runs postero-inferior to the posterior digastric muscle. Once cleared, the fatty tissue can be passed under the accessory nerve in continuity with the neck dissection specimen.

7. *Dissection and clearance around the great vessels.* The dissection now proceeds anteriorly onto and around the IJV. The fascia overlying the posterior aspect of the IJV is incised in a broad front (superiorly and inferiorly), and dissection is carried around the IJV itself. With a left-sided neck dissection and when approaching the IJV inferiorly in level IV, an attempt should be made to identify the thoracic duct on its posterior surface. It is also vital to identify the vagus nerve (Figure 41.7), which usually lies between the IJV and common carotid artery. Superiorly, the hypoglossal nerve will be seen crossing the internal and external carotids. It gives a descending branch (C1) which joins with C2,3 to form the ansa cervicalis. This nerve usually lies antero-lateral to the IJV and should be preserved if possible (if only to show off one's technical expertise!). The sympathetic chain can sometimes be seen on the pre-vertebral fascia deep to the carotid artery, although the dissection itself should not be deeper than IJV.
8. *Anterior dissection.* The limits of the anterior dissection are the anterior border of the omohyoid, and the midline of the neck in the submental triangle. The dissection can proceed quite quickly up the omohyoid muscle. Occasionally a large vein is identified (sometimes after it has been cut!) but this is readily ligated. As the dissection reaches the inferior part of the hyoid bone, care should be taken to re-identify the hypoglossal nerve as it passes into the submandibular triangle. The dissection can now continue from the midline along the lower border of the mandible. The mandibular periosteum can be incised to create a sharp plane of dissection. The submental area is usually quite vascular, due to many branches of the submental vessels. The bleeding is usually controlled with diathermy.
9. *Submandibular triangle.* As the dissection passes along the mandible, the mylohyoid muscle will come into view. The marginal mandibular branch of the facial nerve should be identified (if this has not already been done) and retracted. The FVs can be ligated and retracted superiorly to assist retraction of this nerve (Figure 41.8). Having dealt with these structures, it is easy to retract the mylohyoid, exposing the floor of mouth, and enabling easy removal of the submandibular gland (Figure 41.9). The lingual (superiorly) and hypoglossal nerves (inferiorly) should be identified in the floor of mouth and the submandibular ganglion and duct ligated and divided. At the posterior aspect of the gland lies the facial artery, which loops over the posterior digastric and this requires division. If possible, when a microvascular reconstruction is taking place, this artery should be left as long as possible to facilitate subsequent anastomosis. All that remains is

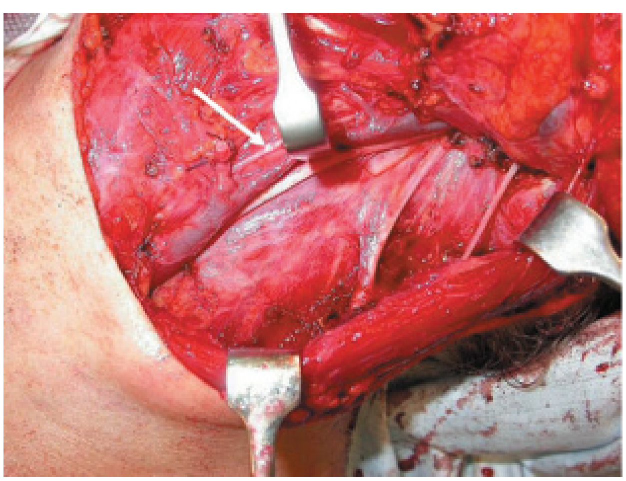

Figure 41.7 Further dissection reveals the vagus nerve and ansa cervicalis (arrowed).

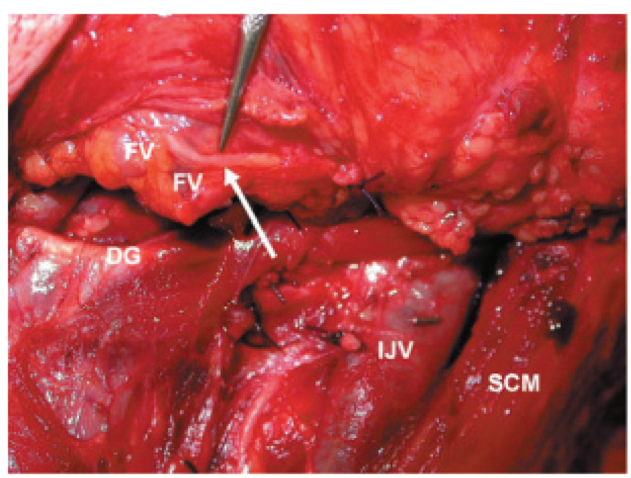

Figure 41.8 Marginal mandibular branch of facial nerve. The facial vessels (FV) have been ligated. DG, digastric tendon.

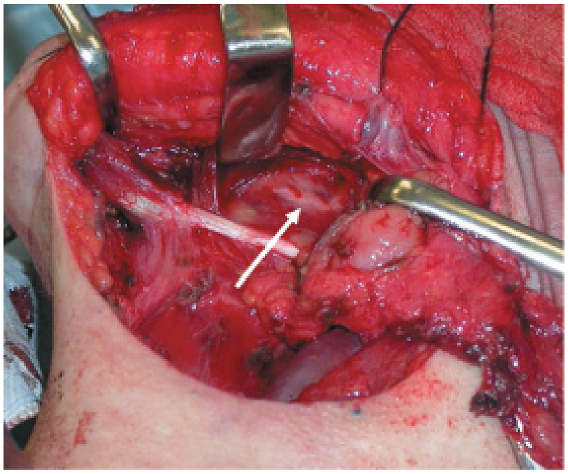

Figure 41.9 Level I clearance. The lingual nerve is arrowed.

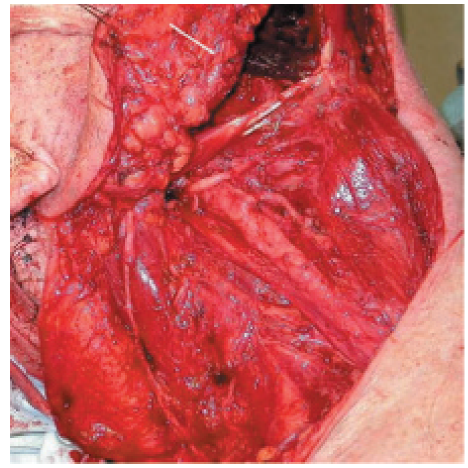

Figure 41.10 Completed MRND type I with preservation of accessory and marginal mandibular nerve (arrowed).

to join up the posterior part of the submandibular triangle with the level II dissection. The tail of the parotid can be included here, and the retromandibular vein will need to be ligated. The specimen should be suitably orientated for the pathologist.

10. *Drains and closure.* Meticulous haemostasis is paramount for this procedure – the patient should be positioned head down to increase venous pressure to visualize bleeding points. A Valsalva manoeuvre given by the anaesthetist to further increase venous pressure is also often helpful. Two large drains (size 16) should be placed. The author routinely uses 3/0 Maxon to close platysma, with either 5/0 Prolene or skin clips to close the skin itself.

Variations – MRND and RND

1. In many respect, the removal of the SCM makes the neck dissection much easier, although adds morbidity for the patient. With a RND or MRND (when the SCM and IJV are included), the SCM can be cut through superiorly and inferiorly using monopolar diathermy. The IJV itself requires careful ligation both superiorly and inferiorly. The author places two 2/0 linen ties with a 3/0-silk transfixation suture between them on the IJV being left. On the part of the vein being removed, it is wise to place a transfixation suture as well, since the ties sometimes come off during the dissection giving an unexpected shock. Since it is low pressure in the IJV, any bleeding can be temporarily arrested with pressure. If a tie came off superiorly at the skull base, it should still be possible to control bleeding with pressure (even suturing packs in place). Once the SCM and IJV are divided, it is easy to use the cut omohyoid muscle belly to rapidly progress the dissection anteriorly. Ideally if possible, the accessory nerve should be preserved in a MRND as should the marginal mandibular nerve (Figure 41.10).
2. Level V can be cleared starting initially inferiorly along the clavicle, again down to the level of the pre-vertebral fascia. Large clips (e.g. Roberts) can be used to clamp the fat (and transverse cervical vessels). These are ligated as one proceeds with the dissection. At this point, care should be taken not to inadvertently pull up the subclavian vessels! This can be prevented by initially dissecting straight down through the fat onto the pre-vertebral fascia. It is also possible to damage the lung apex resulting in a pneumothorax, although this is rare. The accessory nerve can be dissected free and skeletonized from the fat if this nerve is being preserved. The cervical nerves will need to be cut to enable removal of level V, but remember that these should only be cut when they are superficial to the pre-vertebral fascia. It may be necessary to cut the inferior belly of the omohyoid.

Supra-omohyoid neck dissection

The principles of a more selective procedure are the same as for the levels I–IV neck dissection described above, although it can be technically more challenging. The dissection usually starts inferiorly over the omohyoid muscle and proceeds superiorly as before. As with a levels I–IV neck dissection, it is important to mobilize the SCM muscle and take the dissection posterior to the IJV to sample as many nodes as possible.

Effects of radiotherapy

Surgery become more difficult in the irradiated neck, and it is often more difficult to preserve structures, particularly nerves such as the accessory nerve. Tissue planes are distorted, fibrosis makes dissection much more difficult, and bleeding from small vessels can also be a problem. Furthermore, there is a greater chance of wound breakdown (Table 41.1).

Table 41.1 Complications of neck dissection.

Immediate	
Bleeding	Packing, identify vessel, repair if appropriate (involve vascular surgeons if common or internal carotid [rare])
Pneumothorax	Chest drain
Damage to thoracic duct plug	Oversew with 3/0 silk. Use sternomastoid or omohyoid
Inadvertent transaction of nerve	Micro-neural repair
Gross swelling (if both internal jugular vein compromised)	May need tracheostomy
Early	
Chylous leak	Exploration and/or medium chain triglyceride (dietician support)
Haematoma	Evacuate depending on size
Infection	Systemic antibiotics/drain if collection
Wound breakdown	Minimize risk with initial choice of incision and two-layer closure Re-suturing in theatre
Late	
Shoulder pain/dysfunction	Physiotherapy
Contractures	Physiotherapy

Top tips

- Meticulous haemostasis.
- Traction and counter-traction.
- Dissection on a broad front.
- Beware of anatomical variations.
- If you get stuck, start dissecting elsewhere and come back.
- Position patient head down at completion to raise venous pressure and identify bleeding points.

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42

Sentinel node biopsy

MONI ABRAHAM KURIAKOSE and NIRAV PRAVIN TRIVEDI

CONTENTS

BACKGROUND

Lymphatic metastasis generally follows an orderly and predictable pattern of progression beginning with the sentinel lymph node. It has been demonstrated that the status of the sentinel node predicts the presence of metastasis in the remainder of the nodal basin. Lymphoscintigraphy is now established as a reliable and minimally invasive technique of identifying the sentinel nodes in solid tumours. Since the original description to stage patients with cutaneous melanoma, biopsy of the sentinel lymph node has replaced routine elective lymph node dissection in many anatomical regions that include the head and neck. Initial attempts at lymph node mapping using the vital dye, isosulphan blue, failed to localize the sentinel nodes in about 20% of cases. The introduction of the hand-held gamma probe has improved sensitivity to over 93%. This technique is now being increasingly used to evaluate cancer of the breast, colon and vulva, and it is redefining the standard of care for these treatment sites.

Head and neck squamous cell carcinomas (SCC) are considered to have a predictable pattern of metastasis to cervical lymph nodes in previously untreated patients. However, clinical experience may not provide fail-safe information with which to direct therapy for individual patients. It has been reported that 16% of patients with SCC of the oral tongue had 'skip metastases' which bypassed what was considered to be the first echelon nodal basin. This highlights the need for individualized localization of sentinel lymph nodes.

CONCEPT OF SENTINEL NODE

The sentinel node is the first echelon node of the nodal basin. Presence of metastasis to the sentinel node defines the status of the rest of the nodes in the nodal basin (Figure 42.1).

DETECTION OF SENTINEL NODE

Sentinel lymph nodes can be identified by three techniques:

1. Isosulphan blue dye
2. Static lymphoscintigraphy
3. Dynamic lymphoscintigraphy

Isosulphan blue-dye technique involves injection of the dye submucously around the tumour. The sentinel lymph nodes are those which are stained blue. As the technique needs visualization, it is necessary to expose the entire nodal basin, thereby increasing the invasiveness of the procedure. Moreover, the isosulphan blue dye has been proven to have lower reliability than lymphoscintigraphy (Figure 42.2).

Dynamic lymphoscintigraphy involves injection of Tc 99-labelled filtered sulphur colloid at the periphery of the tumour. The flow of radiolabelled dye from the primary tumour to the sentinel nodes can be visualized in real time using a gamma camera operating in a continuous mode. The position of the nodes where the radioactivity localizes can be marked on the skin using a pen (Figure 42.3).

Static lymphoscintigraphy involves identifying the nodes with increased radioactivity using a hand-held gamma probe (Figure 42.4). The sentinel node, which is surgically removed, is submitted for various histopathological, immunohistochemistry and molecular marker examination for the detection of micrometastasis.

INDICATION

Sentinel node biopsy is indicated for early stage (T1, T2) oral cavity SCC of oral cavity with clinically N0 neck.

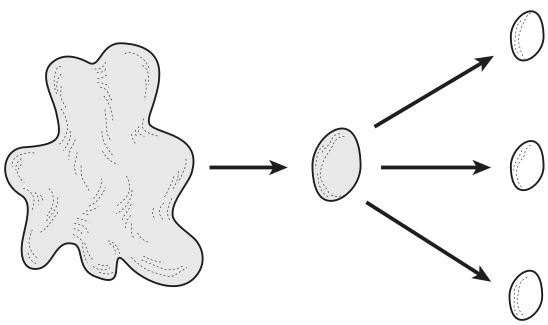

Figure 42.1 Concept of sentinel node.

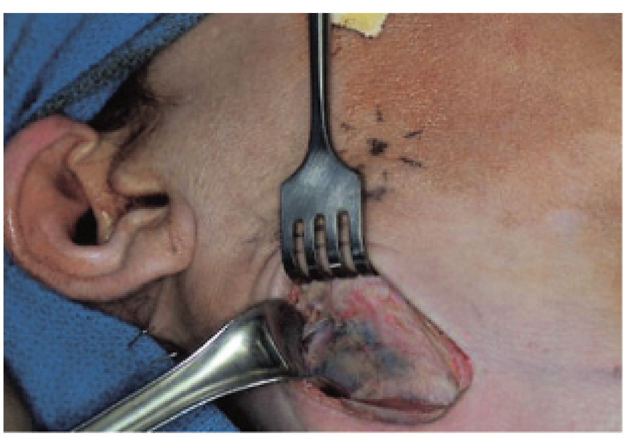

Figure 42.2 Blue-dye technique. (Courtesy of Mark Delacure.)

Figure 42.3 Dynamic lymphoscintigraphy under gamma camera.

Figure 42.4 Static lymphoscintigraphy with hand-held gamma camera.

CONTRAINDICATIONS

Sentinel node biopsy is contraindicated in the following:

- Advanced stage tumours
- Clinical or radiological evidence of nodal metastasis
- In cases where the neck needs to be exposed for other reasons (exposure of donor vessels for reconstructive surgery)

LYMPHOSCINTIGRAPHY

Injection of the dye

A total of 5 mL of Tc 99-labelled filtered sulphur colloid is loaded in an insulin syringe. Between 1 and 2 mL of the sulphur colloid is injected submucously around the tumour (Figure 42.5). This is performed after isolating the tumour with gauze. Care should be taken to avoid spilling of the radioactive material. Should it happen, it should be wiped away with the gauze. Allow the patient to rinse the mouth with saline several times to remove any salivary contamination. It is necessary to instruct the patient to avoid swallowing of saliva contaminated with the radioactive material to avoid misleading images in the gamma

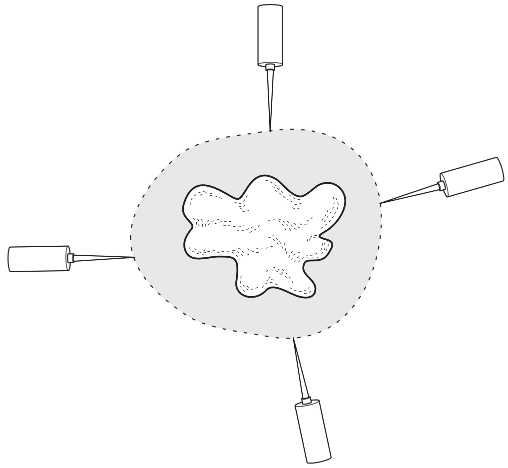

Figure 42.5 Injection of dye into periphery of tumour.

camera. All the radioactive material and contaminant should be disposed of according to the institutional radioactive material disposal guidelines.

POSITION OF PATIENT UNDER THE GAMMA CAMERA

Position the patient on the gamma camera table similar to that in the operation table, using shoulder bag and head ring. This is important as the position of skin marking can change with neck extension in the operating table.

DYNAMIC IMAGING

Beginning immediately after the injections, the patient is positioned with the injection site centred under a large field-of-view dual-head gamma camera. A large field of view, set at 20% window centred on the 140-keV technetium energy peak and fitted with a low-energy, high-resolution parallel hole collimator, is used to follow the disbursement of the radionuclide from the primary site to the cervical lymphatic. Initially, images are captured in an anteroposterior plane to determine the laterality of the sentinel nodes, following which the images are captured in the lateral view (Figure 42.6). The images are captured in a continuous mode. The transit time for drainage of the sentinel node in oral cavity cancer is less than 5 minutes. It is a continuous process where tracking of dye into sentinel nodes can be seen on screen. The primary tumour is seen as a large shadow, while a sentinel node is seen as a smaller shadow. The number of sentinel lymph nodes can vary from two to three in head and neck cancer.

MARKING OF SENTINEL NODES

The position of the sentinel node is marked externally on the neck (Figure 42.7). This serves as a landmark for incision in the neck during the surgery. The location of the sentinel node is marked with the guide of a pointer with

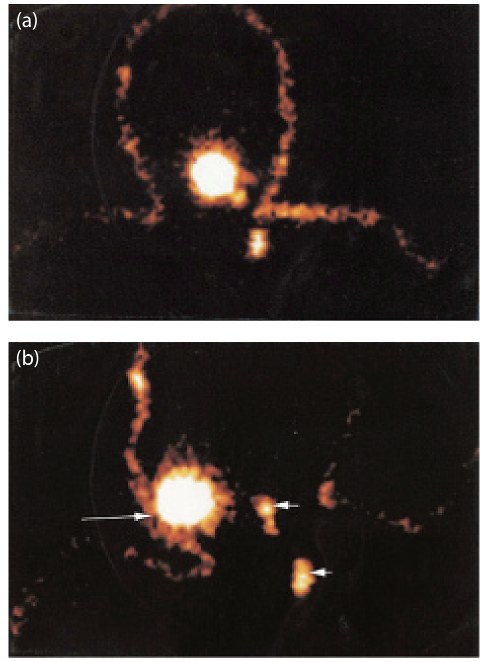

Figure 42.6 Nuclear scan images. Large arrow indicates the primary tumour. Small arrows indicate sentinel nodes.

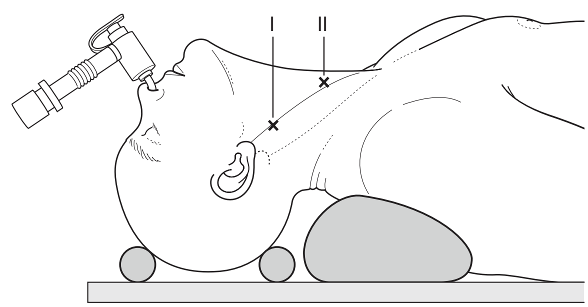

Figure 42.7 Marking of sentinel node externally on neck.

radioactive tip under gamma camera in a continuous mode. The location where the 'hotspot' of the pen and that of the sentinel node coincide is marked on the skin with an indelible pen.

ANAESTHESIA

The operation is performed under general anaesthesia. Nasal intubation is preferred to avoid interference in dealing with the primary tumour in the oral cavity.

OPERATION

Position of the patient

The neck must be hyperextended with the shoulders and occiput supported with a head ring. The neck is rotated to the contralateral side. The operating table is tipped with

a head-up tilt. The head and neck region is prepared and draped in the standard fashion to expose the neck and oral cavity (Figure 42.8).

Surgery of the primary lesion

Emission of radiation from the primary lesion interferes with detection of the sentinel node using the gamma probe, particularly if the node is situated in the region of level I. Excision of the primary lesion in the oral cavity before performing sentinel node biopsy in the neck helps in eliminating this radiation interference.

Neck incision

A transverse neck incision is marked on the neck as in a standard neck dissection. An incision of about 4 cm in length is placed along this marking so as to access the marked sentinel nodes. Occasionally, it may be necessary to make more than one incision. However, all the incisions should be placed in such a way that these incisions should be later extended to perform neck dissection, should it be necessary (Figure 42.9).

Raising flaps

Upper and lower skin flaps are raised in the subplatysmal plane over the region of the marked sentinel nodes (Figure 42.10).

Identification of sentinel nodes

Using a hand-held gamma camera, the background radiation level is noted in the neck in a position away from the sentinel nodes and primary tumour. Using the skin marking and the hand-held gamma probe as a guide, the region of the sentinel node is explored (Figure 42.11). An increase in count of more than threefold, the background is considered significant. This count is noted as an in vivo count. That particular node is removed and the ex vivo count is obtained outside the body to confirm it as a sentinel node. Count of node-bed is noted, which should confirm that the identified node is removed. The procedure is repeated to remove all the marked sentinel nodes. The wound is closed in layers. Drains are not usually required.

SENTINEL NODE PATHOLOGIC EVALUATION

The excised sentinel nodes are sent for histopathological evaluation. Step-sections of the nodes are obtained along the hilum of the node at 3–4 mm intervals. The tissue is processed by haematoxylin and eosin staining. Immunohistochemistry with pan-cytokeratin antibody or CK-14 polymerase chain reaction may be performed to identify submicroscopic metastasis. The clinical relevance of such lesions is yet to be determined. The feasibility of determining metastatic status by frozen section evaluation also needs to be determined.

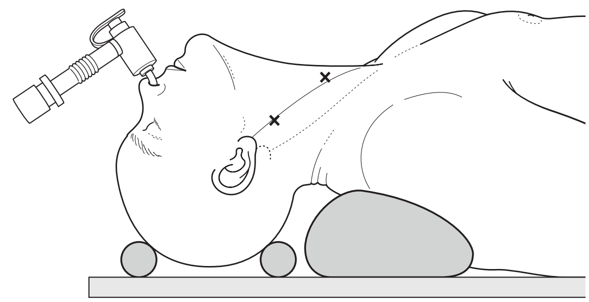

Figure 42.8 Positioning of patient on operation table.

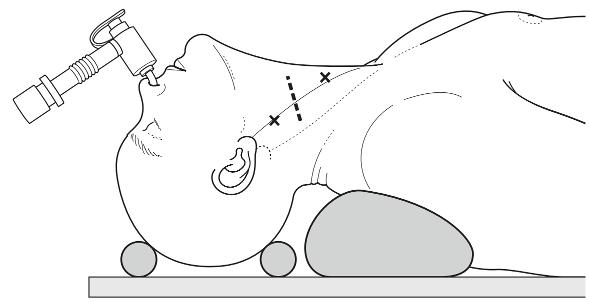

Figure 42.9 Incision in neck.

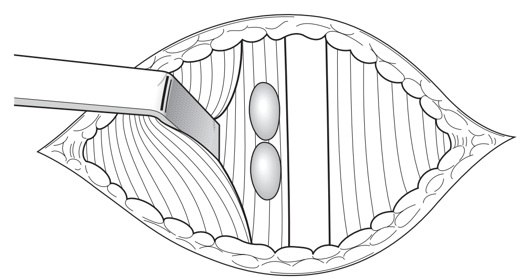

Figure 42.10 Raising of flaps, exposing lymph node groups.

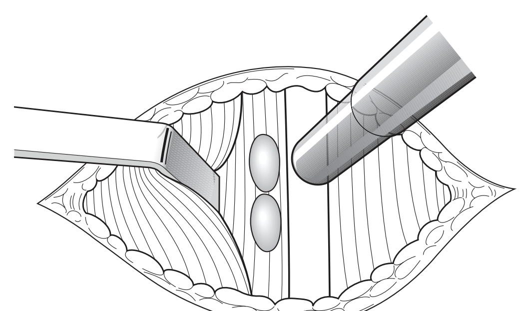

Figure 42.11 Identification of sentinel lymph node with gamma probe.

POST-OPERATIVE CARE

Sutures are removed on day 7. The final histopathological report is evaluated and if any node shows metastasis, formal neck dissection is carried out.

FOLLOW-UP

Regular follow-up of every month for a year and every 2 months for the second year is done. Any suspicious neck mass is thoroughly evaluated with ultrasound scan and fine needle aspiration cytology as deemed necessary.

CONCLUSION

At present, there are no clear guidelines for the management of clinically N0 neck. Lymphoscintigraphy and sentinel node biopsy offer the possibility of minimal invasive management of the N0 neck, avoiding undue morbidity of surgery or radiation, as well as eliminating the risk of regional recurrence. However, efficacy of the procedure and long-term results need to be assessed before implementing it in clinical practice.

Top tips

- Sentinel node biopsy should be performed in a previously untreated patient.
- Care should be taken to avoid spillage of the dye while injecting around the tumour.
- Instruct the patient not to swallow during injection to prevent ingestion of the dye.
- The position of the patient under the gamma camera should be similar to the position to be adopted in the operating room to increase the accuracy of sentinel node marking.
- If the sentinel node is identified in level I, consider removing the primary tumour first to avoid background radiation.

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43

Tumours of the skull base

MADANGOPOLAN ETHUNANDAN, BARRIE T EVANS and DOROTHY A LANG

CONTENTS

Skull base surgery developed principally throughout the 1990s to become an established and clearly defined surgical subspecialty. The service is team based and includes neurosurgeons, oral and maxillofacial, ENT and/or plastic surgeons and ophthalmologists. The team will also include neurointensivists, neuroanaesthetists and neuroradiologists with interventional expertise. Neurosurgical and critical care nursing expertise and a team coordinator are essential.

Skull base tumours generally have neural, vascular or meningeal origins. They may also arise from bone, cartilage and extra-cranial tissues. Although a vast range of different pathological entities is included within the definition, common biological tendencies are observed because of their anatomical location. Management of patients harbouring skull base pathology is complex and surgeons require in-depth anatomical knowledge – usually obtained by cadaveric dissection, and expertise may be required in microvascular anastomosis and neural reanimation.

CLINICAL PRESENTATION

- Neural compression
- Special sense problems
- Cranial nerve dysfunction
- Endocrine dysfunction
- Problems with facial form and function

In general terms, patients harbouring skull base pathology will present with symptoms that for convenience can be classified as aforementioned. The onset and development of clinical features may be insidious because of the relatively slow rate of progression of the majority of tumours. It is crucial to be able to identify and document the pace of progression to ensure timely intervention and pre-empt critical neural decompensation.

Tumours affecting the skull base may be primary or secondary lesions. Metastatic disease in the skull base is not uncommon and biopsy may be required prior to major surgery being undertaken in cases where there is

diagnostic doubt. The source of the primary tumour may not be known until after the result of the biopsy.

PATHOLOGY – BROADLY CLASSIFIED

- Benign, e.g. fibrous dysplasia, meningioma
- Low-grade 'malignant', e.g. chordoma, olfactory neuroblastoma
- Malignant, e.g. squamous cell and adenoid cystic carcinomas, chondrosarcoma, rhabdomyosarcoma and secondary tumours

LOCATION

For convenience, skull base tumours can be classified according to primary location, e.g., anterior cranial fossa (ACF), middle cranial fossa (MCF), posterior fossa (PF) and those arising from the paranasal sinuses, orbit, infratemporal fossa and post-nasal space.

CLINICAL CONSIDERATIONS

A number of factors need to be considered in the setting of a multidisciplinary team meeting (MDT) in order to establish appropriate treatment pathways for these patients. Guidelines issued by *National Institute of Clinical Excellence* (NICE) in the United Kingdom indicate the required expertise. Factors to consider include the following:

- Age and patient comorbidities
- Pathology and tumour biology
- Size and site of the lesion
- Involvement of critical neurovascular structures
- Quality-of-life considerations

An extensive pre-operative workup is required.

- Comprehensive systems review and documentation of neurological deficits.
- Visual function (including acuity and fields as a minimum) will be necessary.
- Formal ophthalmological review may be needed and visual evoked potentials may help assess potential for stabilization/recovery of visual function as well as identify 'sub-clinical' optic nerve failure.
- Olfactory function should be documented.
- Where the lateral skull base is involved, hearing, balance and vestibular function will need to be accurately assessed and noted.

Comorbidity factors require careful evaluation. In general terms, complications occur in up to 20% of patients undergoing major skull base surgery. Those patients with significant comorbidity have a higher risk of complications and will be less likely to recover from peri-operative systems compromise. In patients with established or anticipated lower cranial nerve or bulbar dysfunction, tracheostomy and gastrostomy will be required at an early stage to avoid aspiration pneumonitis and ensure safe adequate nutrition.

IMAGING

Detailed imaging is essential for treatment planning. As a minimum, this will include computed tomography (CT) and magnetic resonance imaging (MRI). Precise delineation of the tumour is required and critical evaluation of anatomically inaccessible areas is required to identify patients who may not fulfil criteria for surgery, e.g. invasion of the cavernous sinus. In some tumours, or in those patients requiring post-operative evaluation, positron emission tomography (PET) scanning may be required to distinguish tumour tissue from post-operative scarring/flaps used in reconstruction and regions displaying post-operative hyperaemia. Angiography will delineate blood supply and identify patients who may need pre-operative embolization. Protocoled CT scans for intra-operative navigation is often necessary to localize critical structures and aid resection.

MANAGEMENT

In determining options for management, it is important to be able to assess the impact of intervention on the natural history of the pathology. Where treatment benefits are marginal, conservative management may be in the patient's best interests. In general, neurological deficits are unlikely to recover with treatment and stabilization will be a more rational objective.

The impact of treatment on the patient's quality of life is a further important consideration. In general, surgery may dramatically alter quality of life adversely in the short and medium term. This is less evident with radiotherapy – none the less the long-term impact of the latter may need evaluation.

MANAGEMENT OPTIONS

- Conservative treatment
- Surgery
- Radiotherapy/stereotactic radiosurgery (SRS)/knifet™
- Combination/sequential

It is important to recognize that 'cure' of this type of pathology may be elusive – this needs to be emphasized in discussions held with the patient and carers. Tumour control in the vast majority of cases will prove to be a more realistic option.

KEY ISSUES

- Complex
- High risk
- 'High tech'
- Resource implications

In addition to an experienced and multi-professional workforce, adequate theatre time, expensive 'high-tech' equipment and the support of a highly trained theatre team are required. Access to neurointensive or critical care facilities is mandatory.

ANAESTHESIA

Fundamental aspects of anaesthesia in skull base surgery include maintenance of haemodynamic stability, control of intra-cranial pressure (ICP), cerebral protection and cranial nerve monitoring. This latter may preclude the use of long-term muscle relaxants. Intermittent pneumatic calf compression is used in conjunction with an agreed policy to reduce the incidence of deep vein thrombosis (DVT) and pulmonary thromboembolism (PTE). Careful positioning of the head is essential to avoid compromise of the neck veins.

EQUIPMENT

Standard equipment will include an operating chair, neurosurgical microscope and increasingly endoscopes and appropriate stacks/screens. Micro-instruments and non-stick bipolar forceps are essential. Image guidance is helpful, but must not be used by the inexperienced to compensate for a lack of anatomical knowledge and surgical expertise. High-speed drills, ultrasonic aspirators and nerve monitors complete the list of essential equipment. Some services have access to intra-operative MRI.

KEY TECHNICAL PRINCIPLES

- Anatomy
- Access (see Chapter 36)
- Resection
- Reconstruction

Anatomy

In planning surgical treatment, a clear understanding of the pathological anatomy is required. Whilst the operating surgeons may be familiar with normal skull base anatomy, the pathological process may distort this. This facilitates planning of the access required, tumour resection and reconstruction of the skull base.

Access

It is fundamental that adequate access to the pathology is realized. This may involve the use of craniofacial osteotomies although with experience their use is rationalized and tailored to the individual patient. A short straight line of sight to the pathology is necessary to create space for surgical manoeuvres and avoid brain retraction. Access should not compromise reconstructive options, e.g., preservation of the superficial temporal and supraorbital vessels. Damage to the temporal muscle should be avoided unless its resection is mandatory. Ideally, osteotomies should be pedicled, if post-operative radiotherapy is planned. Endoscopic surgery can be employed on its own or in addition to open surgery (endoscopic assisted) in selected individuals and specific pathologies.

Resection

In the planning process, the overall strategic approach to the tumour must be determined. The following need to be considered.

- The need for staged surgery.
- Possible multiple access routes.
- The requirement for temporary vascular occlusion, e.g. internal carotid artery. Intra-operative mini Doppler may assist in confirming post-manipulation patency and identify vessels in spasm.
- Microvascular anastomosis or intra-cranial bypass.
- Spinal drainage – a spinal drain may enhance brain relaxation, but the amount of cerebrospinal fluid (CSF) drainage must be carefully controlled by the anaesthetist.
- Steroids, Mannitol and withdrawal of CSF from the basal cisterns and ventricles may also assist with brain relaxation.
- Minimize brain retraction – craniofacial access may assist.

Exposed brain surfaces must be kept moist and where retractors are used, non-stick patties or equivalent should protect the brain. Meningiomas and schwannomas adjacent to the brain will usually have an arachnoidal plane, within which the dissection should be carried out. Damage to the pia should be avoided. Vascular structures are generally dissected parallel to the encased structure and should only be divided after dissection has confirmed that they supply the tumour. Tumour adherent to perforators should be left in situ – tumour eradication should not be preferred to preservation of neurovascular structures.

Dissection en bloc is the ideal with high-grade tumours to avoid tumour spillage. With larger tumours, this may not be possible due to anatomical constraints – in this situation a so-called modified en-bloc resection is performed. The use of the operating microscope is essential in critical areas such as the optic chiasma and cavernous sinus.

Reconstruction

Reconstruction of the skull base is critical to avoid post-operative infection and CSF leak.

- Primary dural closure if possible.
- Repair basal dural defects with vascularized convexity dura or a vascularized pericranial or galeal-pericranial flap passed via a 'letterbox' approach through the convexity dura.
- Tissue glue is helpful to control suture holes and re-enforce suture lines, but will not secure an inadequate repair.
- Small bone defects do not generally need reconstruction but larger defects, particularly over the orbital roof, may need a bone graft, mesh or free tissue transfer to support the dural repair and prevent pulsating exophthalmos.
- The majority of middle fossa defects can be reconstructed with a pedicled temporalis muscle graft. Extensive defects may require free tissue, e.g. rectus abdominis, particularly if the temporalis muscle is devascularized in the resection.

KEY AREAS

- Frontal sinus – if entered is usually cranialized.
- Central skull base – bone not required in isolated central skull base defects. In more posterior defects particularly in older patients, reliance cannot be placed on pericranial flaps; galeo-pericranial flaps are preferred.
- Orbit – orbital roof reconstruction prevents pulsating exophthalmos. Isolated lateral wall defects may not need reconstruction.
- 'Dead space' may allow accumulation of post-operative clot and may be a focus for infection and allow brain herniation. In the central skull base, this may cause traction injury to the optic apparatus. Free tissue reconstruction is usually required in extensive defects.

INDICATIONS FOR FREE TISSUE TRANSFER

It is relatively unusual to require free tissue transfer to reconstruct the skull base. The relative indications include the following:

- Previous radiotherapy/operation
- Complex defects/craniofacial defects
- Failure of a locoregional flap

There are a number of options that can be considered. The choice of flap will depend on the requirement for bulk to obliterate dead space or lining to close a basal defect without altering the intra-cranial volume. For the former, a wide variety of muscle or musculo-cutaneous flaps are suitable, e.g. rectus abdominis/latissimus dorsi/anterolateral thigh. For the latter, in our practice, the most frequently used flap is radial forearm for central skull base defects. This versatile flap is used without the cutaneous component to produce a thin fascial flap on a long vascular pedicle.

COMPLICATIONS

Infection is the most dreaded complication of skull base surgery. When this occurs in the setting of an inadequate primary repair, control will only be possible when vascularized tissue is introduced to create a barrier between the intra- and sub-cranial regions.

CSF pathway problems are the next most frequent complication. Whilst the majority settles with temporary CSF drainage, a persistent CSF leak will require further surgery and hydrocephalus may necessitate placement of a shunt.

General medical complications including respiratory tract infection, post-traumatic epilepsy, urinary tract infection and poor nutrition are not uncommon. These are best treated after prompt recognition in a neurointensive care or critical care unit.

ILLUSTRATIVE CASES

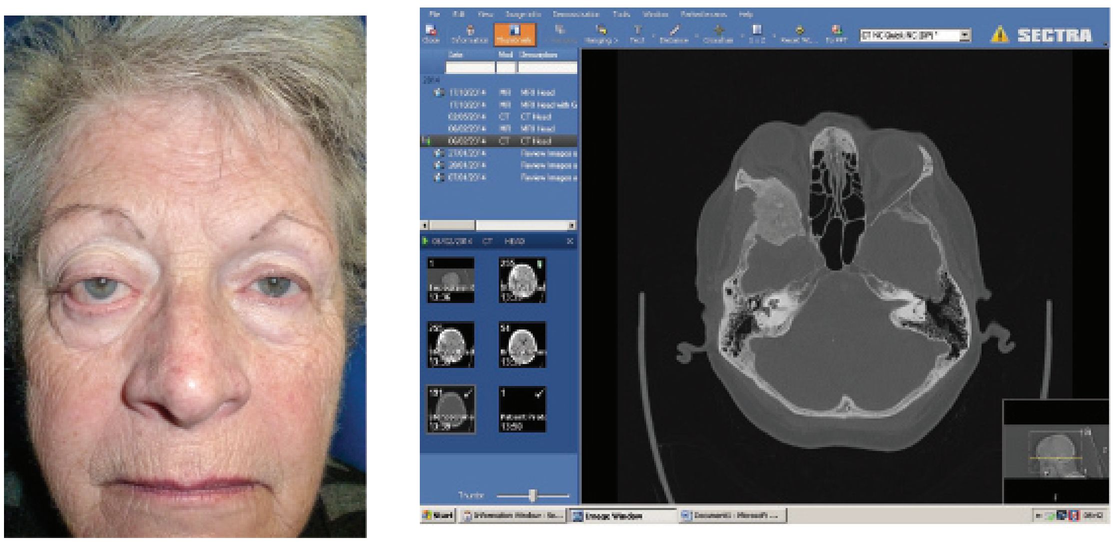
The three cases discussed have been selected to illustrate different tumour sites, pathology reconstructive techniques and management difficulties.

Case 1: Sphenoid wing meningioma en plaque

This is a difficult tumour to control. The ideal is total resection (Simpson Grade 1) but around the skull base, this may be precluded by extensive basal dural involvement and proximity to critical neurovascular structures. In general, patients with visual failure and those with proptosis resulting in ophthalmological complications will require craniofacial resection and reconstruction. In our series of patients, the majority (92%) presented with proptosis and the orbit and MCF were involved in 71%. Whilst technically benign, there is a propensity for this tumour to cross anatomical barriers, invade adjacent structures and recur despite initial surgery considered to be complete.

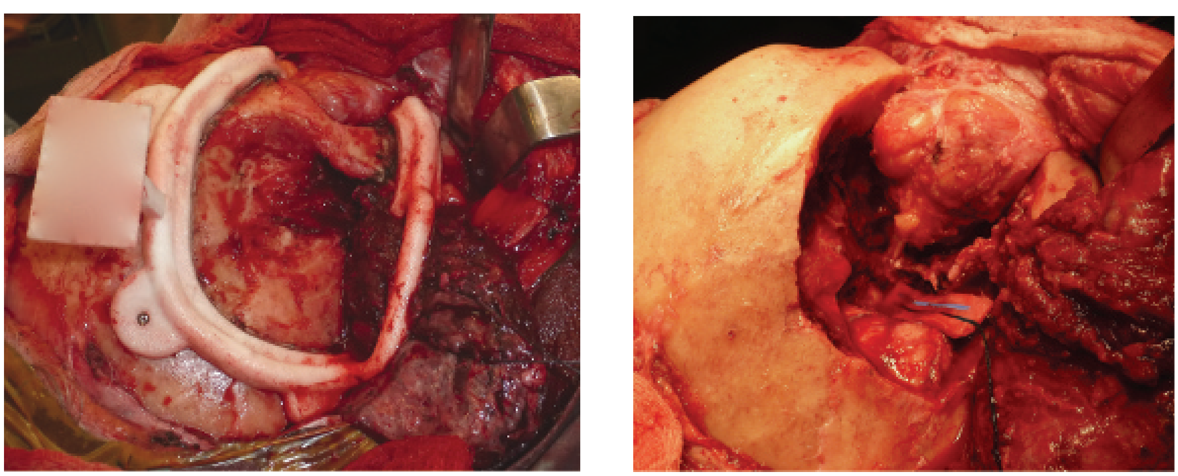
The conventional surgical strategy includes preservation of vision, improvement of aesthetics and prevention of the inevitable ophthalmological complications of the untreated primary process.

In most cases, a frontotemporal or pterional craniotomy will be required and lateral/superior orbitotomies may enhance access to the intra-orbital tumour and resection of the bone around the superior orbital fissure and optic canal under direct vision. It is probable that invaded bone in the vault and skull base will require removal. In cases where the temporalis muscle is invaded, this will require resection. Imaging findings may dictate that the superior orbital fissure is decompressed together with the foramina rotunda and ovale. Infiltrated periorbita will then be resected. The optic canal will usually require radical bony decompression and soft tissue compressing the optic nerve will require removal. In patients who have required resection of more than one orbital wall, an orbital reconstruction will be required. In these cases, the use of surgical guides and patient specific implants significantly improves the accuracy of the reconstruction and decreases intra-operative surgical time (Figures 43.1 through 43.3). When these aids are not available, split calvarial bone grafts and/or titanium mesh can be utilized (Figures 43.4 and 43.5).



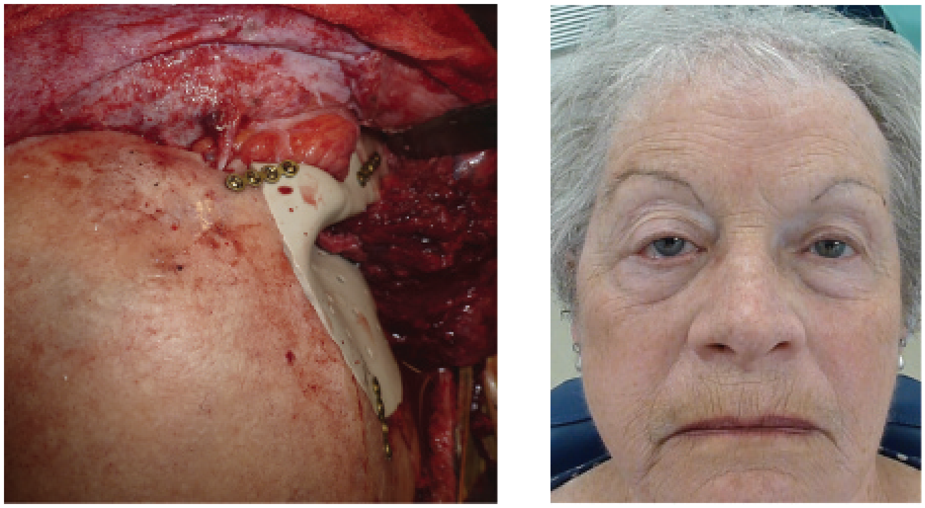
(a) (b)

Figure 43.1 Sphenoid wing meningioma en plaque. (a) Pre-operative proptosis right eye. (b) Axial computed tomography (CT) scan demonstrating hyperostosis of the sphenoid wing.



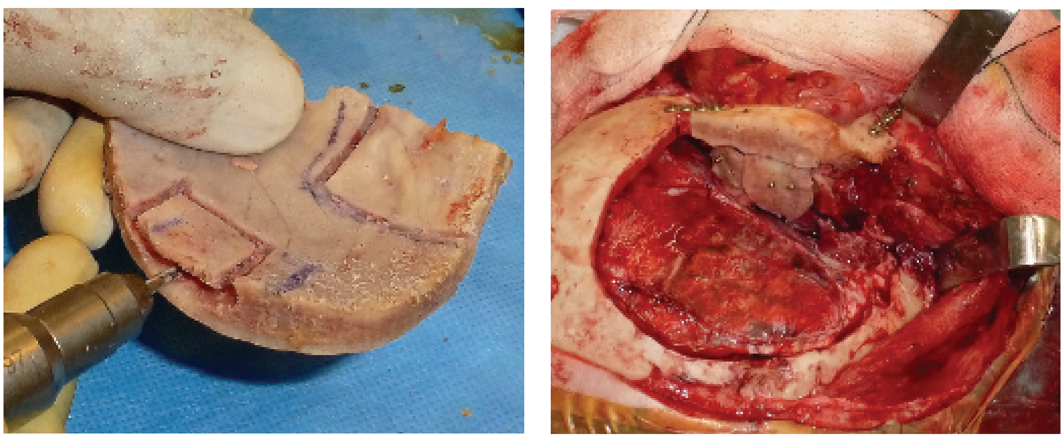
(a) (b)

Figure 43.2 (a) Planed resection with surgical guide in situ. (b) Defect following resection of tumour, optic nerve and superior orbital fissure decompression.



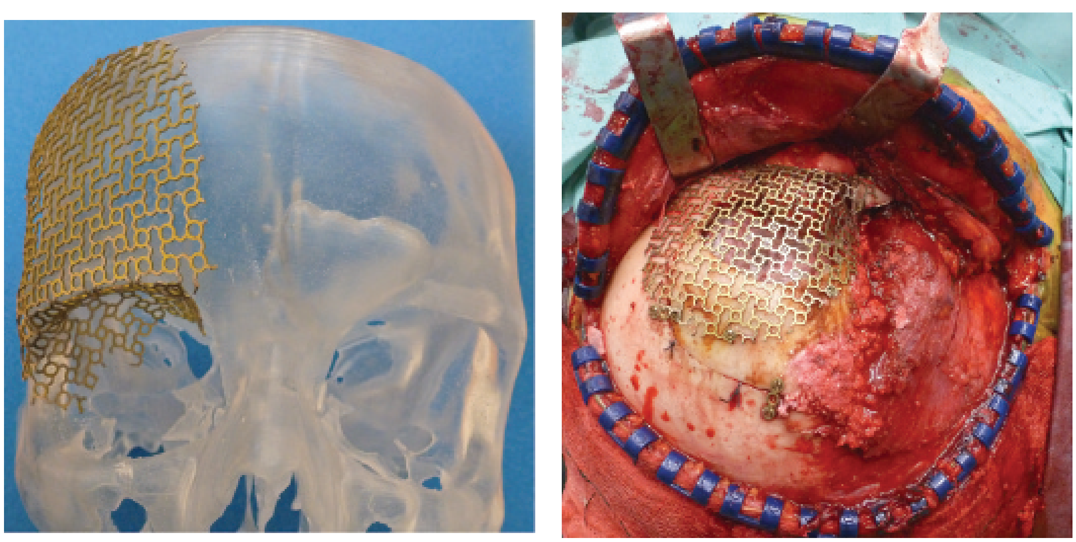
(a) (b)

Figure 43.3 (a) Custom made PEEK implant in situ. (b) Post-operative appearance demonstrating excellent cosmesis with preservation of sight and eye movement.



(a) (b)

Figure 43.4 (a) Harvesting split inner table calvarial grafts. (b) Reconstruction of orbital walls.



(a) (b)

Figure 43.5 (a) Contoured titanium mesh on a mirrored model. (b) Pre-contoured mesh in situ.

Case 2: Craniofacial resection with curative intent

A significant proportion of malignant tumours considered for craniofacial resection will originate from the paranasal sinuses. Various factors have to be taken into account to assess local resectability and include involvement of the brain, dura, orbital structures, nasal cavity, temporal/infratemporal/pterygopalatine fossa and skin. The adjoining structures can be considered as specific compartments and involvement of these compartments will mandate partial/complete resection of the respective compartments.

This patient presented with proptosis and ophthalmoplegia due to an abdominal type adenocarcinoma involving the right maxillary/ethmoid sinuses/nasal cavity/orbit extending superiorly through the cribriform plate to involve the dura, but not the brain and posteriorly to involve the infratemporal fossa (Figure 43.6). Access was obtained via a modified Weber–Fergusson incision, coronal flap, soft-tissue nasal swing and bifrontal craniotomy (Figure 43.7). (Lip split marked for access to the posterior maxilla/infratemporal fossa, but not utilized; inferior dental/lingual nerves traced to skull base with early coronoidectomy). He underwent a craniofacial resection, which included a bifrontal craniotomy, extended maxillectomy with infratemporal fossa clearance, orbital and nasal exenteration and ACF resection including the dura. Vascularized pericranial flap was utilized to line the floor of the ACF and separate the cranial contents from the nasal cavity; maxilla and orbit reconstructed with composite fibula and anterolateral thigh free flaps (Figures 43.8 through 43.12).

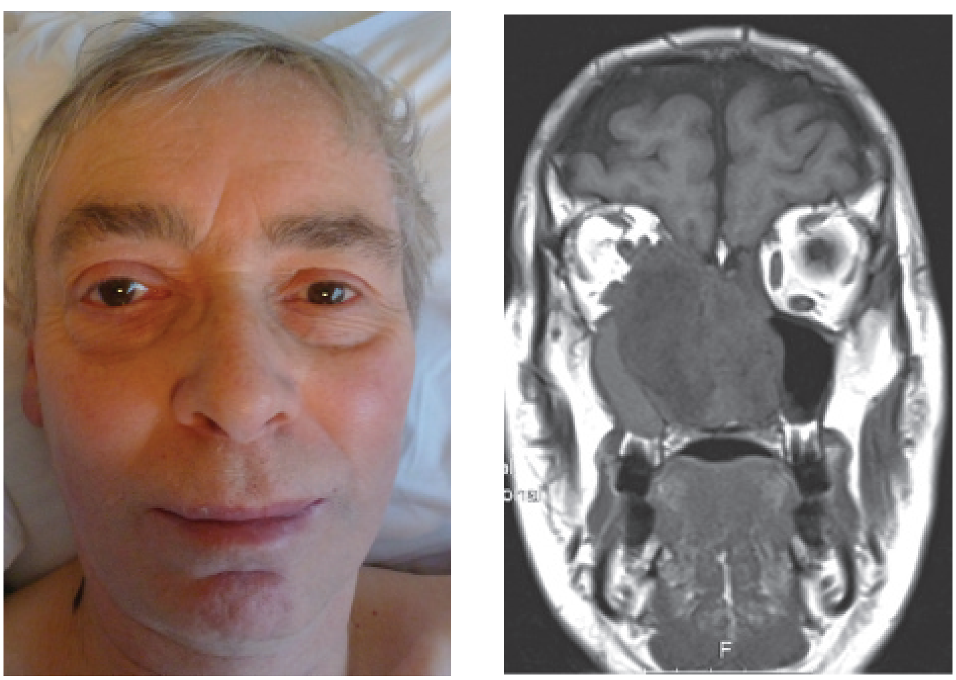
The excisions margins were clear of tumour and he received post-operative radiotherapy due to the extent and adverse histological features of the tumour. He remains well and free of recurrence 18 months following surgery.

Case 3: Cranio-orbital resection with palliative intent

Interventions with palliative intent are considered to alleviate unpleasant symptoms and enhance/maintain quality of life. These often take the form of pharmacological interventions, radiotherapy and psychosocial support. Surgery, however, can have an important role to play in selected individuals to achieve similar aims.

This patient presented with a new metastatic deposit from a thyroid carcinoma in the left orbital apex/sphenoid wing causing significant pain, proptosis and decreasing vision (Figure 43.13). The tumour was considered radio-resistant, as the spinal metastasis had not responded to radiotherapy. The patient was otherwise well, lived independently and continued to work.

Following discussion at the MDT, the patient underwent a frontotemporal craniotomy, superior/lateral orbitotomy and excision of the tumour including the affected temporal bone, temporalis muscle and decompression of the optic nerve and superior orbital fissure (Figure 43.14). The defect was reconstructed with a custom made polyetheretherketone (PEEK) implant and the resections were performed with a surgical guide (Figure 43.15a). The patient made an uneventful recovery and was discharged home 3 days following surgery, completely symptom free



(a) (b)

Figure 43.6 (a) Pre-operative appearance. (b) Coronal magnetic resonance imaging scan.

Figure 43.7 Access incisions marked.

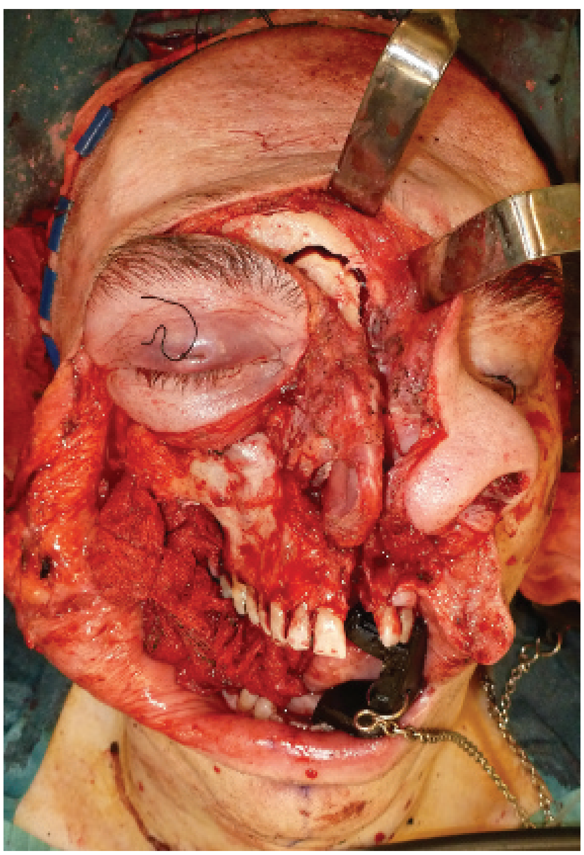


Figure 43.8 Soft-tissue cheek and nasal swing flaps retracted. Facial bony cuts outlined.

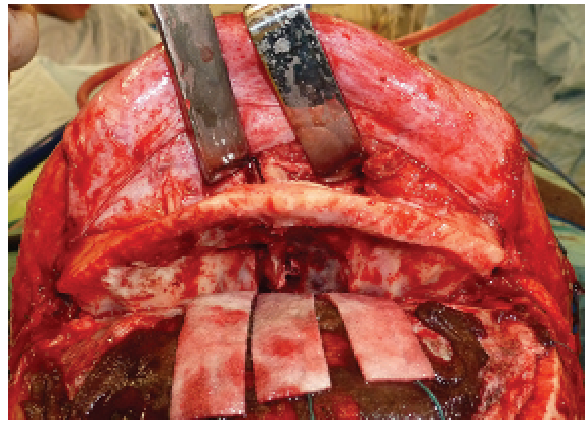
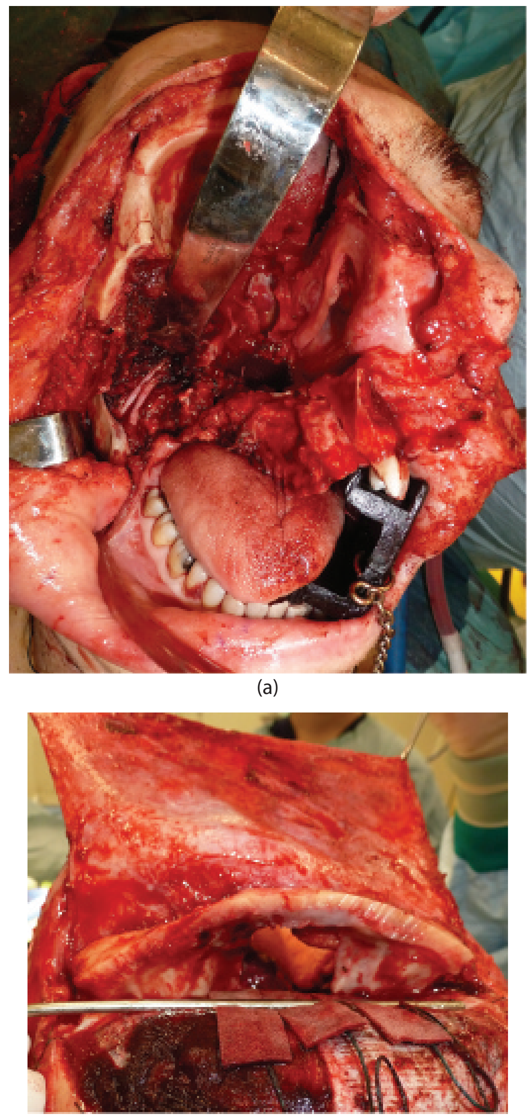


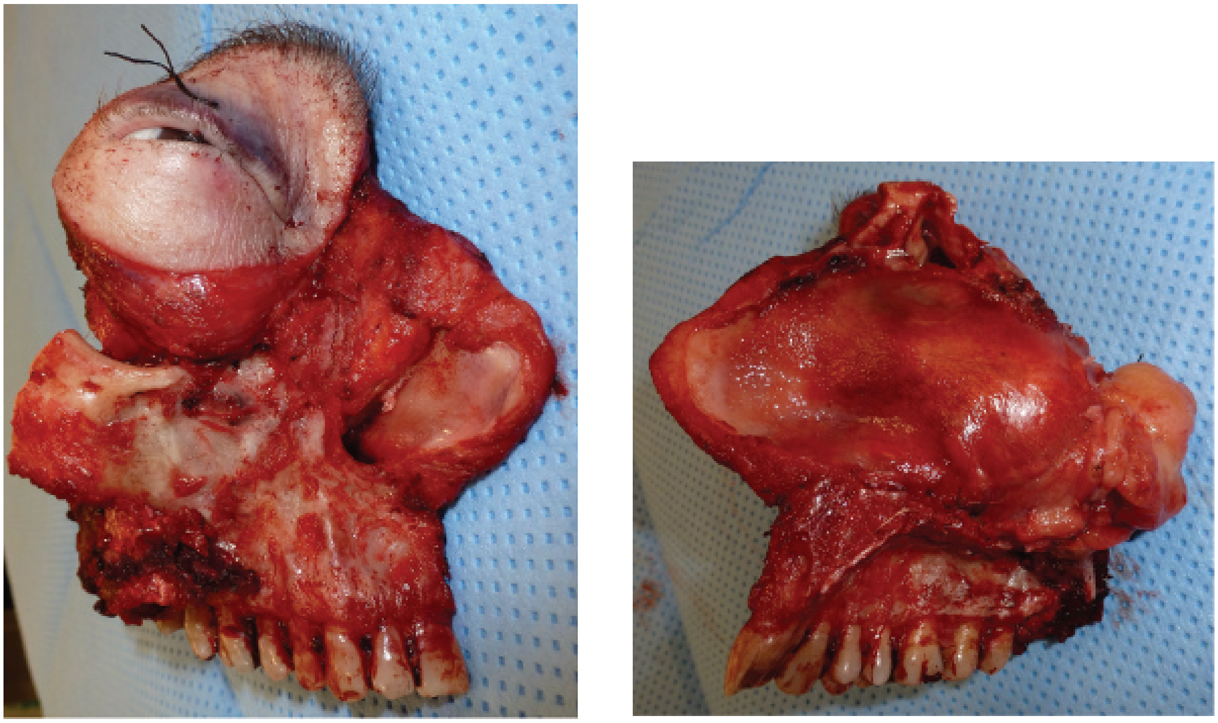
Figure 43.9 Orbital roof/cribriform plates delineated via a bifrontal craniotomy.



(a)

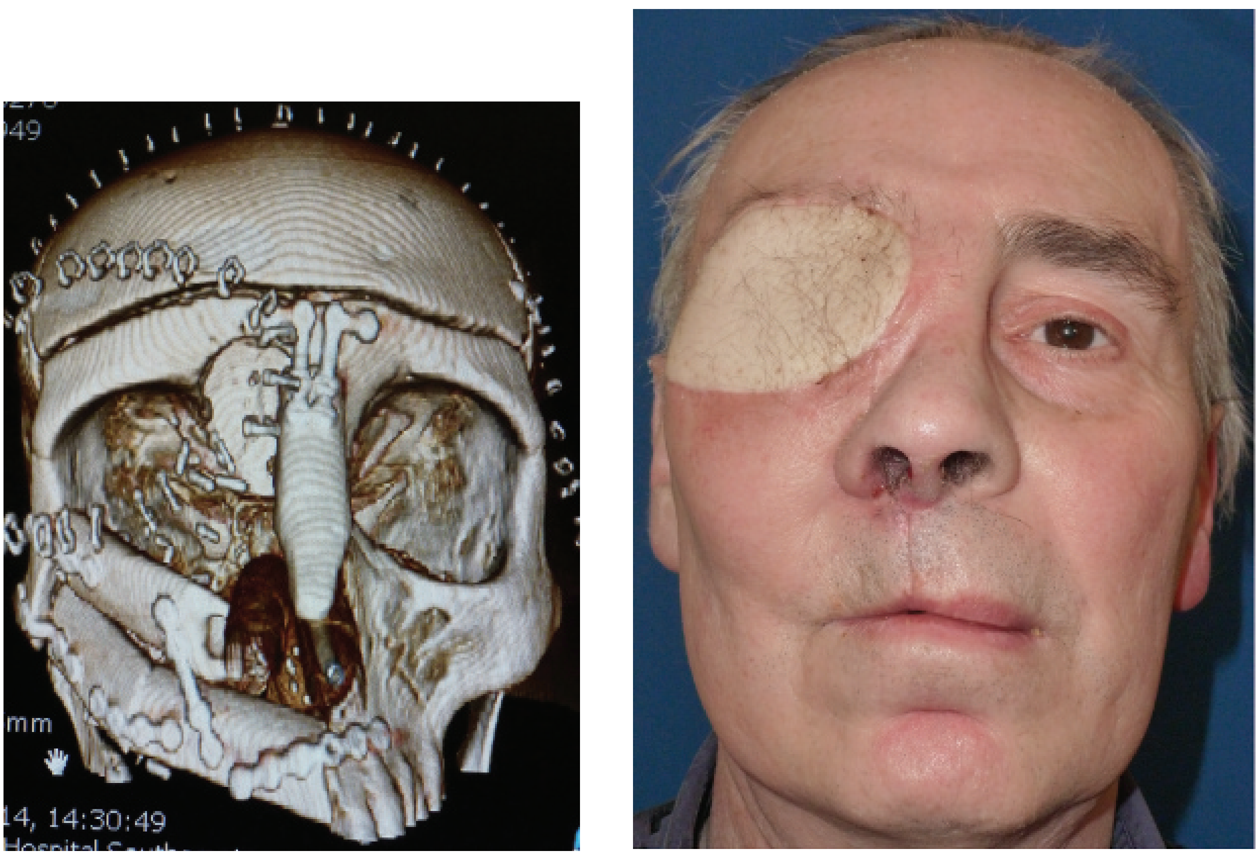
(b)

Figure 43.10 (a) Mid-facial defect following resection of tumour; inferior dental/lingual nerves traced to skull base. (b) Skull base defect following resection of orbital roof/cribriform plate; pericranial flap held out.



(a) (b)

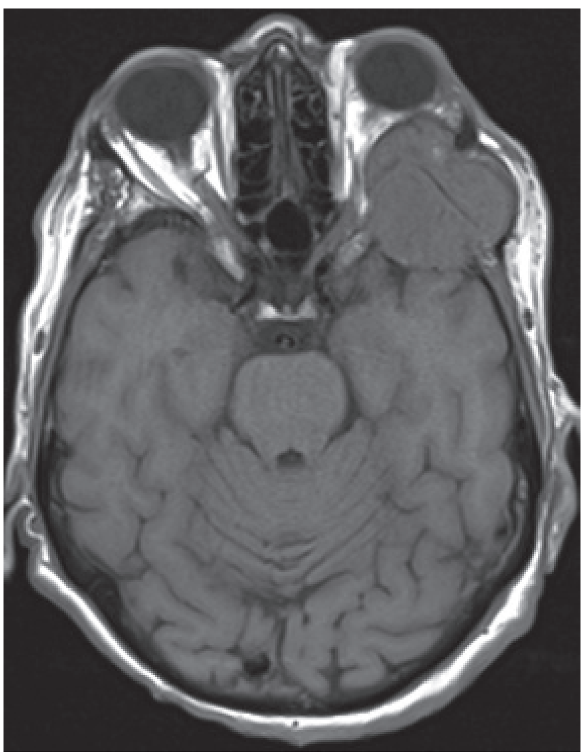
Figure 43.11 (a and b) Specimen demonstrating en-bloc removal of tumour.



(a) (b)

Figure 43.12 (a) Post-operative three-dimensional CT scan demonstrating bony reconstruction. (b) Early post-operative appearance.

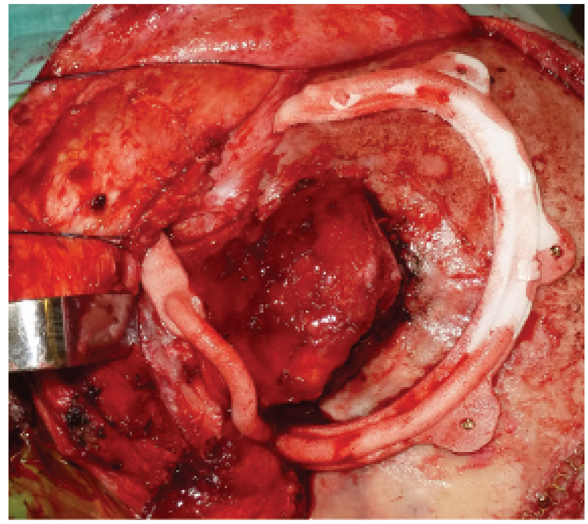
(a)



(b)

Figure 43.13 (a) Pre-operative appearance with proptosis. (b) Axial MRI demonstrating the lesion.

with intact vision and eye movements (Figure 43.15b). The patient returned to work 3 weeks later and died of disseminated disease 6 months later, with no recurrence of her orbital symptoms.



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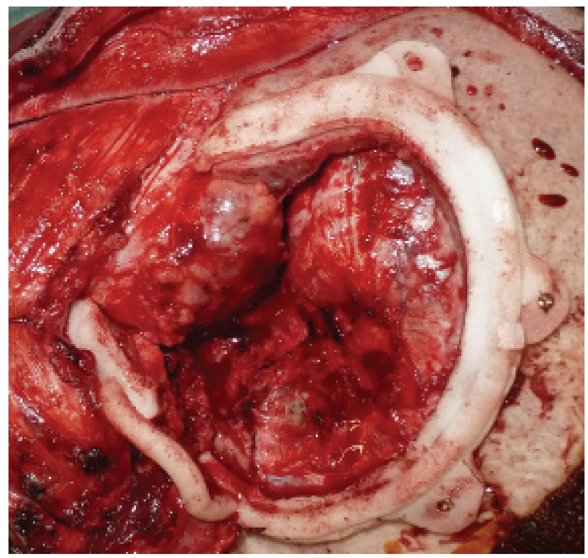

(b)

Figure 43.14 (a) Resection margins outlined with the surgical guide. (b) Defect following resection of tumour.

This patient highlights the potential difficulties in deciding the appropriate treatment in complex cases – balancing the surgical morbidity versus quality of life, which in this case was enhanced despite the limited post-operative course.

Stereotactic radiosurgery

Patients are becoming aware of these treatments and frequently request their use in preference to surgery. Surgeons must be able to provide reasoned argument for the pros and cons of these forms of irradiation in tumour control.

- Control tumour growth
- Control not equivalent to cure
- No validated comparison with natural history

(a)

(b)

Figure 43.15 (a) Custom made PEEK implant in situ. (b) Appearance 2 weeks post-op.

Advantages

- Single (few) outpatient treatments
- No operation

Disadvantages

- Total eradication exceptional
- Long-term uncertainty in biological behaviour
- Lifetime follow-up required
- Options need to be fully and openly discussed

Top tips

- Skull base surgery should only be contemplated with the appropriate skill mix in a multidisciplinary team.
- Many skull base tumours are slow growing, and clinical and imaging surveillance play a key role in patient management.
- Sound applied anatomical knowledge is essential to link sub-cranial with intra-cranial dissection.
- The use of appropriate access osteotomies may facilitate cerebral protection by minimizing brain retraction whilst maintaining a wide corridor of access to the pathology.
- Sub-total tumour resection, particularly in benign and low-grade malignant tumours will frequently provide adequate tumour control, provide relief from symptoms and minimize morbidity.
- The key elements in reconstruction are the isolation of intra-cranial contents from the nasal cavity and paranasal sinuses and appropriate support for the frontal and temporal lobes if required. Autologous tissue is the preferred reconstructive option.
- Follow-up protocols will depend on tumour biology – recurrence is expected with certain tumours including chordoma and meningioma.
- Management recommendations are based on accurate and unbiased information.
- Surgeon's objectives and technical achievement need to be aligned with the expectations of patients and their carers.

SUGGESTED READINGS

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SECTION V

SALIVARY GLAND AND THYROID SURGERY

44

Submandibular, sublingual and minor salivary gland surgery

JOHN D LANGDON

CONTENTS

PRINCIPLES AND JUSTIFICATION

The most frequent indications for excision of the submandibular gland are when a calculus is present within the gland hilum and cannot be retrieved endoscopically or when the gland is the site of chronic infection or when a benign or malignant tumour is present. Only 10% of salivary tumours arise in the submandibular gland and 60% of these will be pleomorphic adenomas. The remaining 40% will be malignant. Except in advanced malignancy, the tumours rarely extend beyond the capsule of the gland and so excision of the submandibular gland is the definitive surgical treatment. For advanced malignant tumours with spread beyond the capsule, more radical clearance of the submandibular triangle is required, often in continuity with a neck dissection. When a pre-operative diagnosis of a benign tumour can be reasonably and confidently established by computed tomography (CT) and ultrasound-guided fine needle aspiration cytology or preferably fine needle core biopsy and the tumour is in the superficial part of the submandibular gland partial excision of the gland is possible. This has the merit of preserving gland function and reduces the risk of damage to the lingual and hypoglossal nerves.

There are only two indications for the removal of the sublingual gland. The first is in the management of a ranula and the other is when a tumour is present. The sublingual gland is a very rare site of tumour, but almost all of them will be malignant, the majority being adenoid cystic carcinomas. The most frequent reason for operating on the minor salivary glands is for mucocoele or for tumour. Nearly 10% of salivary tumours arise in the minor glands and about 50% of these will be malignant.

Investigations

When there is a history suggestive of obstruction, plain radiographs (mandibular occlusal and oblique lateral views) are appropriate as the majority of submandibular stones are calcified. A sialogram should not be performed unless a calculus has been ruled out on plain film as the sialogram itself might displace the stone proximally, making surgery more difficult. For the investigation of chronic infection, a sialogram is invaluable. It will show the extent of the destruction of the acinar cells and the post-stimulation emptying film will demonstrate residual function.

If the gland is not functioning, it should be removed as an elective procedure to prevent further episodes of infection.

When a mass is present either in the submandibular gland or the sublingual gland, a CT scan or a magnetic resonance imaging (MRI) scan is indicated. The scan should include the neck so that any associated lymphadenopathy is also imaged. For suspected minor salivary gland tumours, if they occur within the lips, cheeks or floor of the mouth, simple excision biopsy is the investigation of choice. However, for tumours arising on the hard palate, imaging with a CT or MRI scan is mandatory to assess the depth of the tumour.

Biopsy

Open surgical biopsy of a suspected submandibular gland tumour is contraindicated. If the tumour is contained within the capsule of the gland, open biopsy will spill tumour cells into the surrounding tissue planes. As the majority will be benign pleomorphic adenomas, their straight forward excision will be compromised. If the tumour is malignant, then the hope of cure will have been compromised. Fine needle aspiration biopsy appears to be safe but is unreliable because of sampling error in salivary gland pathology, but ultrasound-guided fine needle core biopsy is useful if available.

For suspected minor gland tumours arising in mobile soft tissues (lips, cheeks and floor of the mouth), excision biopsy will often be the only treatment required. If the tumour proves to be a high-grade malignancy, furthermore extensive surgery might be required together with post-operative radiotherapy when indicated. The situation is different when a tumour arises from the hard palate. In this situation, an incisional biopsy is mandatory as the diagnosis will have a direct influence on the extent of the subsequent surgery.

SURGICAL REMOVAL OF STONES IN THE DISTAL SUBMANDIBULAR DUCT

Wherever facilities are available, a first attempt at endoscopic or Dormia basket retrieval should be attempted (see Chapter 45). However, on occasion this is either not available or is unsuccessful in which case open surgery is required. If the stone lies within the lumen of the duct distal (anterior) to the point where the duct crosses the lingual nerve, it is a safe procedure to open the duct and remove the stone. For stones more proximal, great care must be taken to avoid damage to the lingual nerve and often it may be wise to remove the submandibular gland together with the stone from an external approach.

Anaesthesia

In a co-operative patient, the operation is readily performed under local anaesthesia. If co-operation is in doubt, a general anaesthetic should be used. If the operation is to be performed under local anaesthesia, 2% lignocaine hydrochloride with 1:80,000 epinephrine (adrenalin) is used. A lingual nerve block plus local infiltration suffices. Care must be taken not to infiltrate too much solution immediately over the duct as this can easily distend the floor of the mouth and make it difficult to identify the duct. It is also important not to perforate one of the sublingual veins as this will result in a large haematoma.

Operation

The first stage is to pass a stay suture into the floor of the mouth around the duct proximal to the position of the stone. This prevents the stone from being displaced backwards during the operation. The ends of the suture are left long and should be held in artery forceps. Gentle traction on the suture will then lift the duct upwards making it more accessible in the floor of the mouth (Figure 44.1).

An incision is made in the mucosa along the line of the duct overlying the stone. The blade is used in a gentle stroking fashion gradually becoming deeper until the wall of the duct is opened. The duct itself is seen as a pale grey structure with an overlying capillary network (Figure 44.2).

It is often helpful to steady the duct with dissection forceps while incising longitudinally through its wall. Often the calculus is seen through the duct wall and the overlying incision immediately releases it. If the stone is large and there has been scarring and fibrosis, it may be adherent to the lining of the duct. In this situation, fine stay sutures can be inserted into the duct wall on each side of the stone and these sutures can be used to retract the walls. The calculus can be gently mobilized and freed with the careful use of a fine artery clip or small dental excavator (Figure 44.3).

Once the calculus has been released, cloudy mucinous saliva will often be released from the duct proximally.

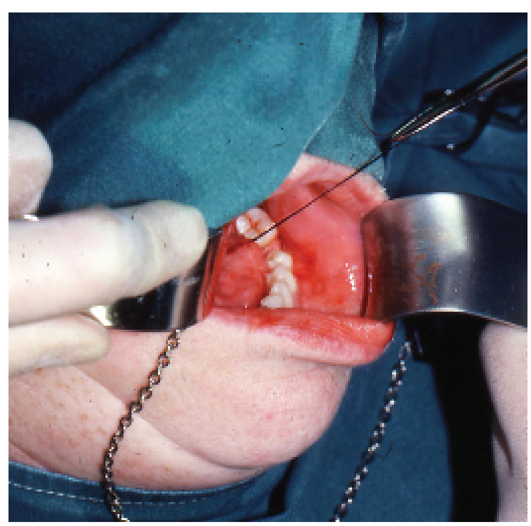

Figure 44.1 Stay suture around the submandibular duct proximal to the site of the stone.

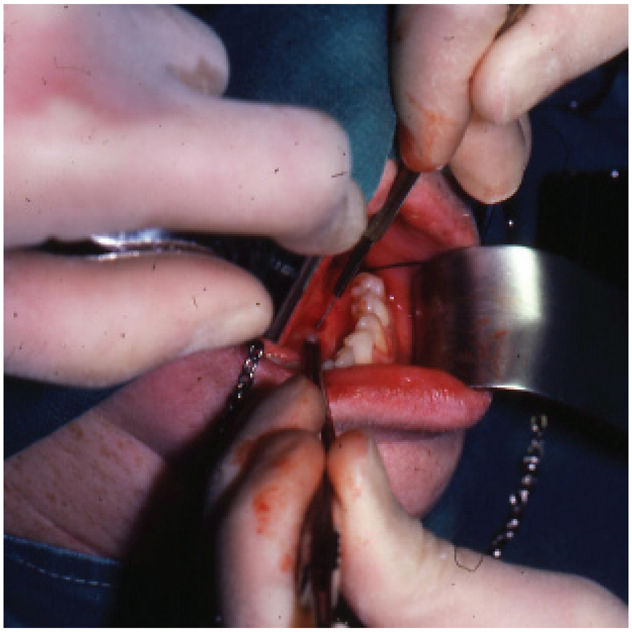

Figure 44.2 A linear incision is made in the floor of the mouth to expose the submandibular duct.

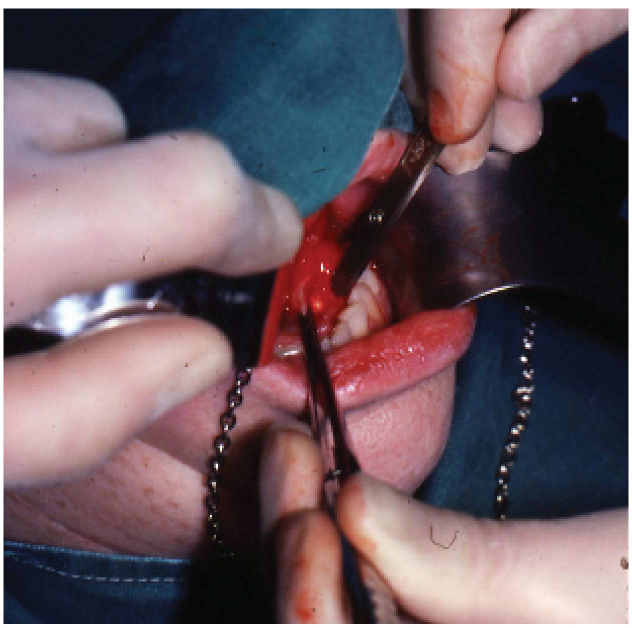

Figure 44.3 The stone is exposed and released.

The duct should be gently irrigated with sterile saline or water both proximally and distally to ensure that any further epithelial casts or gravel are removed. If these are retained, they readily act as foci for further stones to form (Figure 44.4).

The stay sutures are removed and the mucous membrane of the floor of the mouth is closed with two or three resorbable sutures. No attempt should be made to close the duct walls as this would result in scarring and stricture formation leading to further obstruction (Figure 44.5).

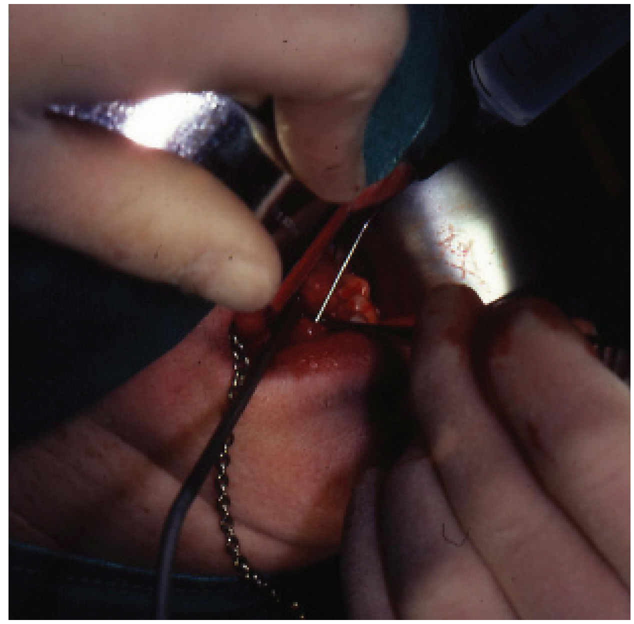

Figure 44.4 The duct is irrigated both proximally and distally to ensure that no 'gravel' remains.

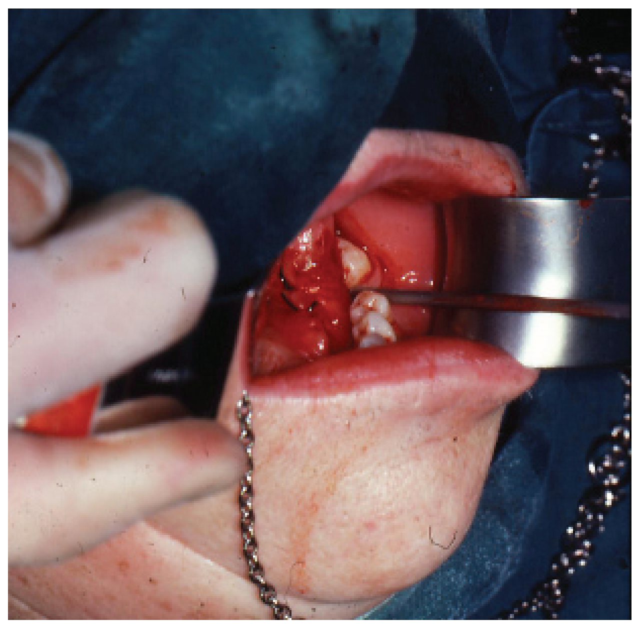

Figure 44.5 The floor of mouth mucosa is closed with one or two sutures.

SURGICAL REMOVAL OF STONES IN THE PROXIMAL SUBMANDIBULAR DUCT

Anaesthesia

Access to the posterior floor of the mouth is difficult in the conscious patient and for this reason general anaesthesia is preferred. Once the patient is on the operating

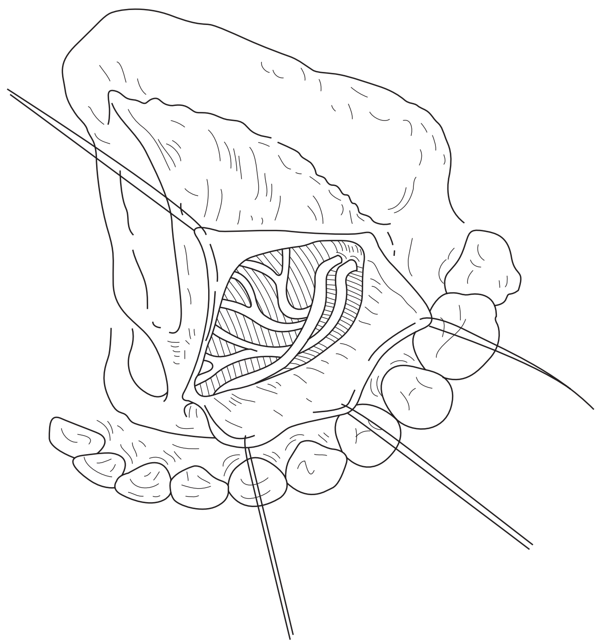

Figure 44.6 Incision in the floor of the mouth for removal of a stone at the hilum of the submandibular gland.

table, it is helpful to infiltrate the floor of the mouth with local anaesthetic containing epinephrine (adrenalin) as this helps to reduce bleeding. Care must be taken not to perforate one of the sublingual veins.

Operation

An assistant is essential. The operator should stand on the contralateral side. A mouth prop is inserted between the molar teeth on the side of the stone. The assistant grasps the tongue with a swab or alternatively a sharp pointed towel clip can be used. The tongue is retracted forward and away from the side of the stone. An incision is made through the mucosa of the floor of the mouth laterally from the third molar region forward and medial to the sublingual gland (Figure 44.6).

The sublingual gland is then retracted laterally using one or two stay sutures revealing the submandibular duct on its deep surface. Using careful blunt dissection, the duct is traced posteriorly identifying the lingual nerve passing immediately deep into the duct running from the lateral border of the tongue towards the third molar tooth (Figure 44.7).

Once the duct and the lingual nerve have been identified, they must be carefully separated and the duct traced posteriorly into the hilum of the submandibular gland. At this point the lingual nerve lies very superficially and is ‘tethered’ to the gland itself through the parasympathetic ganglionic fibres (Figure 44.8).

The assistant should apply firm pressure in the submandibular region in order to elevate the hilum of the gland and the proximal duct upwards above the level of the mylohyoid. At this point, the stone is readily palpable. A longitudinal

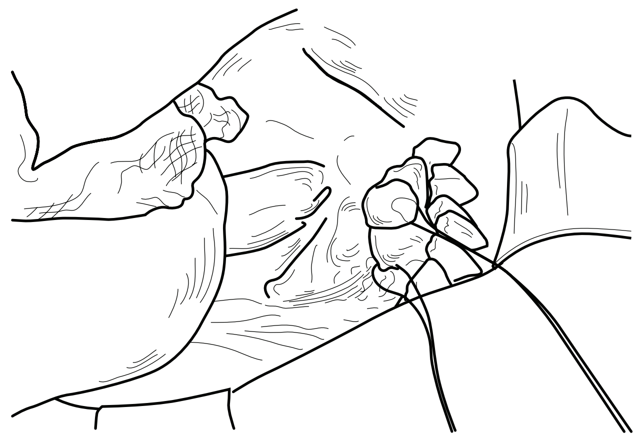

Figure 44.7 Following retraction of the sublingual gland the lingual nerve can be identified deep to the submandibular duct.

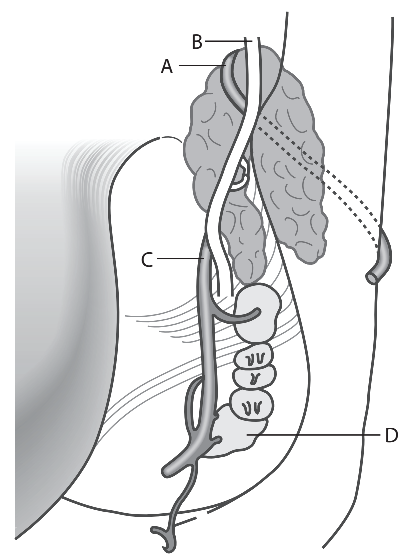

Figure 44.8 Posteriorly the lingual nerve ascends towards the skull base crossing the duct as it enters the hilum of the submandibular gland. (A) Facial artery; (B) lingual nerve and submandibular gland; (C) submandibular duct; (D) sublingual gland.

incision is made through the duct wall and the stone is teased out using a small excavator (Figure 44.9).

The duct is then carefully irrigated in order to wash out any associated ‘gravel’. No attempt is made to close the duct wall. Careful use of the diathermy ensures haemostasis. All stay sutures are removed and the mucosa of the floor of the mouth is closed with two or three resorbable sutures.

Post-operative care

As the stone and obstructed gland is likely to be infected, a 3-day course of antibiotics is given. Routine analgesia is used and the patient should be encouraged to eat citrus fruit or to chew gum in order to encourage salivary flow.

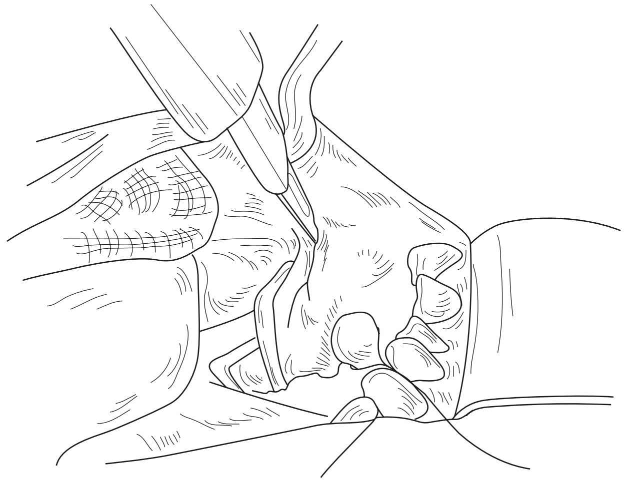

Figure 44.9 The hilum of the gland is incised to release the stone.

SUBMANDIBULAR GLAND EXCISION

Anaesthesia

The operation is performed under general anaesthesia. The patient is placed supine on the operating table with moderate neck extension and the chin rotated to the opposite side. It is helpful to have head-up tilt of the table as this reduces venous engorgement. Following routine skin preparation and draping, the incision is mapped out. The incision line should be infiltrated with conventional dental local anaesthetic containing 2% lignocaine hydrochloride and 1:80,000 epinephrine (adrenaline). This results in some vasoconstriction which limits capillary ooze and helps to define tissue planes.

The incision

The incision should run within a natural skin crease in the neck at least 3 cm below the lower border of the mandible in order to avoid damage to the mandibular branch of the facial nerve as it loops down below the lower border of the mandible (Figure 44.10). It should be at least 7 cm long. The lower the incision in the neck, the better the post-operative cosmetic result, but incisions lower than 3 cm make the operation slightly more difficult as the operator must dissect upwards to reach the submandibular triangle.

The incision is made with either a No. 15 blade or with a fine diathermy needle or ceramic blade while the assistant puts tension across the incision line. The incision is made directly down to platysma. The subcutaneous fat is stripped with firm pressure with a swab from the underlying muscle for approximately 1 cm on each side of the incision as this facilitates a layered closure. The underlying platysma is then incised to the full extent of the skin incision, again using either a blade or diathermy.

Figure 44.10 Incision marked out in a natural skin crease in the neck.

The assistant can now retract the wound margins using 'cat paws' or Allis forceps applied to the cut edge of the platysma (*never* the skin edges!). The underlying investing layer of the deep cervical fascia is next divided, preferably with scissors, after the fascia is first tented outwards with toothed forceps. Often the fascia consists of a series of separate laminae like an onion skin, but occasionally it is composed of a single thicker sheet. Again the fascia should be divided along the full length of the incision to avoid the operative field becoming even smaller (Figure 44.11).

Posteriorly, the fascial incision approaches the angular tract where the deep cervical fascia splits to form the investing layer that has just been incised and the deeper layer that forms the floor of the submandibular triangle containing the submandibular gland.

The marginal mandibular branch of the facial nerve normally runs on the deep aspect of the investing layer of fascia, although, occasionally, it lies between the platysma and the fascia. Great care must be taken to protect this branch. Even with an incision as low as 3 cm below the lower border of the mandible, the nerve may be encountered when the fascia is divided. If it is seen, it should be carefully mobilized and gently retracted with the upper part of the flap.

The delicate capsule overlying the gland is then lifted with toothed dissection forceps and opened with scissors. The loose connective tissue is separated with scissors to expose the surface of the gland (Figure 44.12). The anterior facial vein which lies in the connective tissue overlying the submandibular gland is clamped, divided and tied.

From now on, the dissection continues as close to the surface of the gland as possible. In the case of chronically infected glands, there is frequently extensive fibrosis and care and patience is required to maintain this plane. For all tumours contained within the submandibular gland capsule, the operation should proceed in the plane just superficial to the capsule as it is an effective barrier between the tumour and adjacent structures. When the tumour is known to be benign and lies superficially within the gland then only that part of the gland needs to be excised using a careful extracapsular dissection. For malignant

tumours that have extended beyond the capsule, a full submandibular clearance, usually as part of a neck dissection, and often including the periosteum of the lower and inner aspect of the mandible, is needed (Figure 44.13).

The anterior pole of the superficial lobe of the submandibular gland is first mobilized and retracted upwards with Allis forceps (Figure 44.14). This reveals the posterior belly of the digastric which is then gently retracted downwards with a small Langenbeck retractor. This then exposes the facial artery which emerges from behind the stylohyoid muscle and passes upwards and forwards to enter the deep surface of the submandibular gland. The artery is then clamped, divided and tied. Great care must be taken to secure the proximal ligature. As the vessel is divided, it retracts out of site and, if the ligature slips, the bleeding end of the vessel can be very difficult to identify.

The course of the facial artery is variable. Often it deeply penetrates the substance of the gland to emerge again at its upper border. Sometimes the artery lies in a groove in the deep aspect of the gland. The dissection continues to mobilize the anterior pole of the superficial lobe of the gland which is then gently retracted posteriorly. During this dissection, a number of small arteries and veins will be identified entering the gland. These should be carefully clamped, divided and tied or diathermized according to their size. As the dissection continues posteriorly along the lower border of the mandible, the facial artery and anterior facial vein are encountered as they hook around the lower border. These vessels are again clamped, divided and ligated.

Sometimes when the facial artery runs in a groove on the deep aspect of the submandibular gland, it can be preserved without division at the lower edge of the gland and again at the lower border of the mandible. However, although this is technically possible, there is little advantage other than to show off one's technical expertise.

At this stage in the operation, the anterior pole of the superficial lobe of the gland can be retracted posteriorly to reveal the groove between the superficial and deep lobes of the submandibular gland. The posterior border of the mylohyoid lies within this groove. It is gently freed with scissors and then retracted forward with a Langenbeck retractor. The deep lobe of the gland can now be mobilized either with a finger or by opening the blades of the scissors applied to the surface of the gland. On the deep aspect of the deep lobe, one or two small veins may be encountered running from

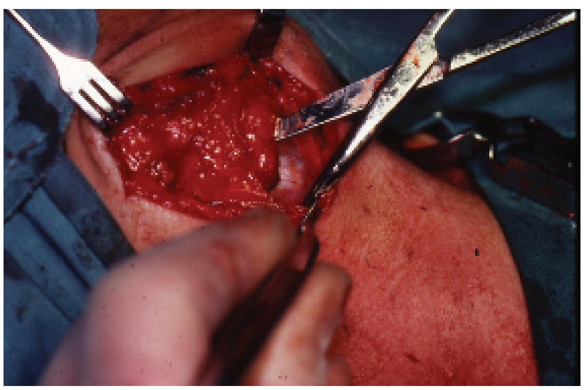

Figure 44.11 Division of the deep cervical fascia following skin incision and division of the platysma.

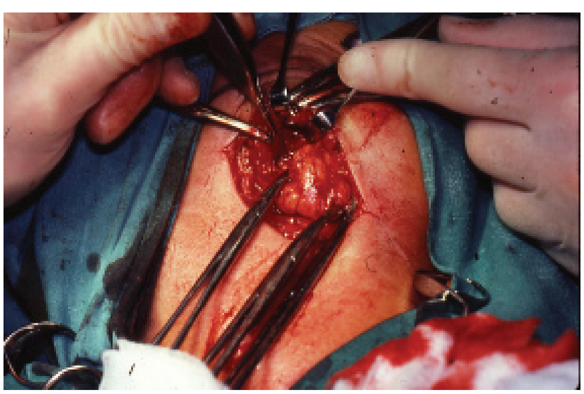

Figure 44.12 Exposure of the submandibular gland revealing branches of the facial vessels.

Figure 44.13 Surgery for a malignant submandibular tumour with cervical metastasis.

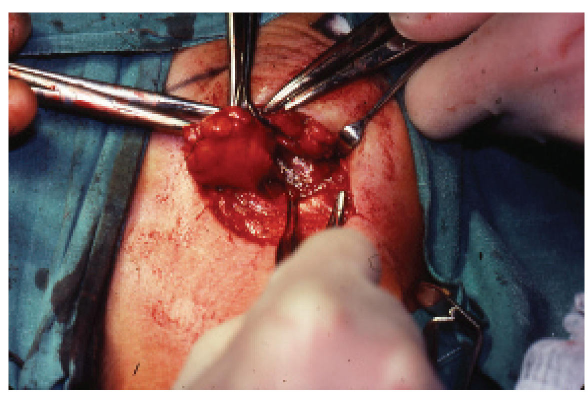

Figure 44.14 The lower pole of the submandibular gland is mobilized and retracted upwards.

the gland through the underlying hyoglossus muscle into the lingual veins. If these veins are not tied off or adequately diathermized, troublesome bleeding may be encountered.

The submandibular salivary gland can now be pulled downwards revealing the V-shaped lingual nerve (Figure 44.15). The apex of the V is the point at which the parasympathetic fibres tether the lingual nerve to the salivary gland. Occasionally, the sublingual ganglion can be identified on the surface of the gland. It is very important to identify the V of the lingual nerve and its parasympathetic fibres as the latter must be transected to free the gland. As these fibres are cut, the lingual nerve springs upwards. Finally, the submandibular duct is clamped, divided and ligated as far forward as possible with just enough remaining to drain the sublingual gland. A thin layer of loose connective tissue remains in the gland bed overlying the hypoglossal nerve (Figure 44.16).

The wound is inspected for any bleeding points, a vacuum drain inserted and closed in layers using a subcuticular suture to close the skin. The wound edges may be reinforced with skin closure tapes.

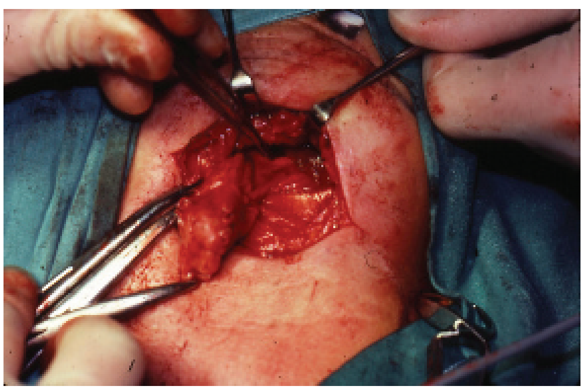

Figure 44.15 The submandibular gland is pulled downwards revealing the V-shaped lingual nerve prior to division of the parasympathetic nerve fibres.

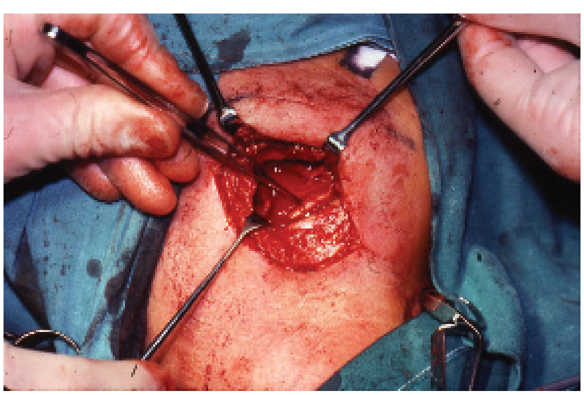

Figure 44.16 The hypoglossal nerve lies in the floor of the gland bed.

Post-operative care

The vacuum drain is removed when drainage has slowed, usually at 24 hours. The subcuticular stitch is removed at about 10 days.

Complications

Three cranial nerves are at risk during removal of the submandibular salivary gland: the mandibular branch of the facial nerve, the lingual nerve (a branch of the third division of the trigeminal nerve) and the hypoglossal nerve. A neck incision at least 3 cm below the lower border of the mandible and careful surgical technique will avoid damage to the facial nerve.

When chronic infection and subsequent fibrosis have occurred, it is sometimes difficult to identify the lingual nerve and the deep aspect of the deep lobe may be tethered to the hypoglossal nerve. At these stages of the operation, the surgeon must be convinced that these structures have been identified before using any sharp dissection.

Meticulous haemostasis is required throughout the operation as many vessels entering and leaving the submandibular gland are only apparent when the gland is under traction and as soon as they are divided the vessels retract into the adjacent muscle planes. Ligation or disposable titanium vascular clips are safer than diathermy in this situation. Carelessness with these vessels results in extensive haematoma in the neck.

SUBLINGUAL GLAND EXCISION FOR RANULA OR EXCISION BIOPSY

The operation may be performed under general anaesthesia or local anaesthesia. If a general anaesthetic is used, it is helpful to infiltrate the floor of the mouth with a local anaesthetic containing vasoconstrictor before any incision is made.

Incision

For simple excision of the sublingual gland, a linear incision is made in the floor of the mouth parallel to and just lateral to the submandibular duct. Care must be taken not to extend the incision posteriorly beyond the first molar tooth so as to avoid damage to the lingual nerve. The incision should open the sac of the ranula to allow the mucinous contents to be aspirated.

Isolation of the submandibular duct

The submandibular duct is now carefully identified and retracted medially. Stay sutures passed through the margins of the mucosa are helpful to aid retraction (Figure 44.17). Using blunt dissection with scissors, the lingual nerve is identified.

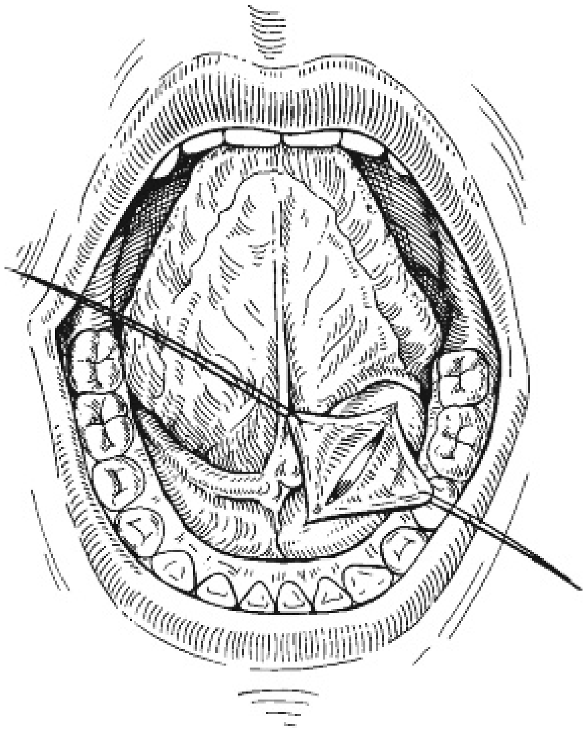

Figure 44.17 Stay sutures retracting the sublingual mucosa.

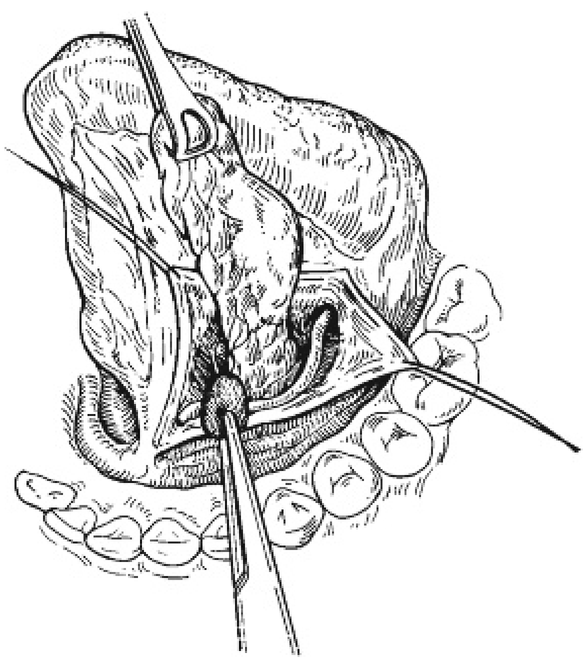

Figure 44.18 Mobilization of the sublingual gland.

Mobilization of the sublingual gland

The sublingual gland which lies adjacent to the inner cortex of the mandible is then mobilized and its multiple ducts, which drain into the submandibular duct, divided carefully in order not to damage the duct itself (Figure 44.18).

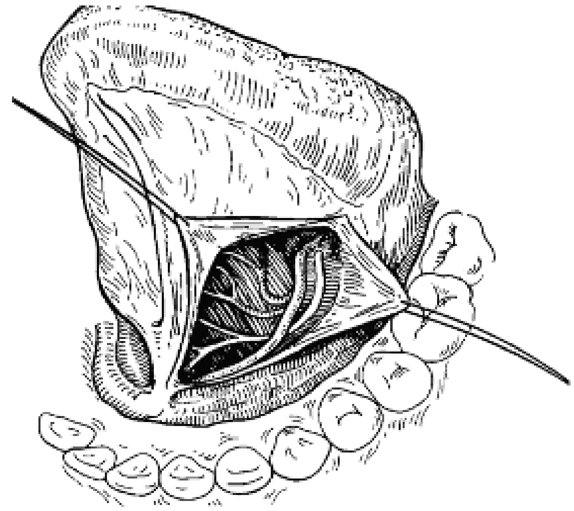

Figure 44.19 Anatomical features displayed following removal of the sublingual gland.

The anterolateral part of the sublingual gland may be attached to the periosteum of the mandible by fibrous tissue and this too must be divided (Figure 44.19). Following removal of the gland, the mucosa of the floor of the mouth is loosely closed with two or three resorbable sutures.

Complications

Damage to the lingual nerve posteriorly or the submandibular duct medially is avoided by careful surgical technique. Meticulous haemostasis is required to avoid a post-operative haematoma in the floor of the mouth.

SUBLINGUAL GLAND EXCISION FOR MALIGNANT TUMOUR

Although only a rare site for a salivary gland neoplasm, the majority of such neoplasms will be malignant and therefore removal should encompass a clear margin of normal tissue of at least 1 cm in all dimensions. This normally includes the adjacent floor of the mouth and mylohyoid muscle, a cuff of ventral tongue and a rim resection of the mandible. If the mandible is edentulous, removal of the inner table only is often sufficient. Each tumour should be managed on its merits according to its size and infiltration into adjacent anatomical planes.

The operation

Because of the vascularity of the floor of the mouth, it is helpful to use a cutting diathermy for the soft-tissue incisions (Figure 44.20). Depending upon the position of the

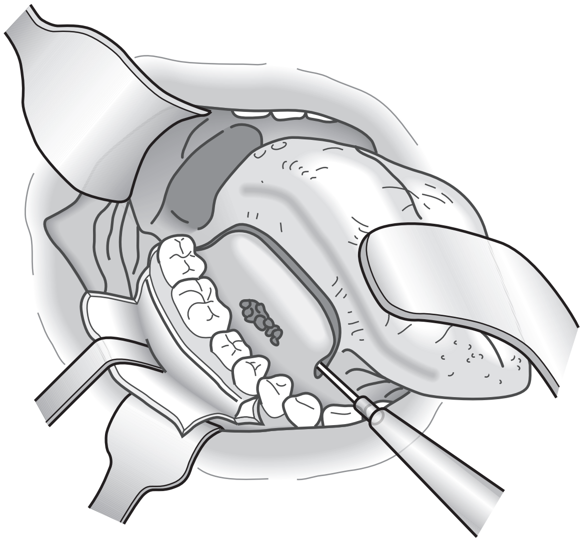

Figure 44.20 Sublingual tumour resection necessitating wide excision with a margin of normal tissue.

sublingual gland and the size of the tumour, it may be necessary to take a section of the lingual nerve with the specimen.

The mandibular alveolus is approached from the buccal aspect. A bur is used to cut the bone horizontally below the level of the tooth roots. The lingual line of section must lie below the level of the mylohyoid insertion (Figure 44.21). Final separation of the alveolus is made with a fine osteotome.

The line of the dissection is then continued across the floor of the mouth deep to the mylohyoid. The mobilized alveolus and sublingual gland within the floor of the mouth must be gently elevated and the hypoglossal nerve, just below the mylohyoid, must be identified and freed. The dissection is then continued to join up with the mucosal incision in the ventral tongue (Figure 44.22).

The buccal mucosal flap is used to cover the mandibular bone. The mucosal defect in the floor of the mouth is closed either by mobilizing adjacent soft tissue or a pack soaked in Whitehead's varnish may be sutured over the defect which granulates and epithelializes below the pack.

Complications

The ensuing complications will depend on how radical the excision has been and what adjacent structures have been resected or damaged. The proximal stump of the submandibular duct should be loosely sutured to the oral mucosa at the back of the operation site. It will form a new opening into the floor of the mouth and submandibular gland obstruction is not a problem. Lingual anaesthesia from loss of the lingual nerve and tongue paralysis, if the hypoglossal nerve has been included in the specimen, are

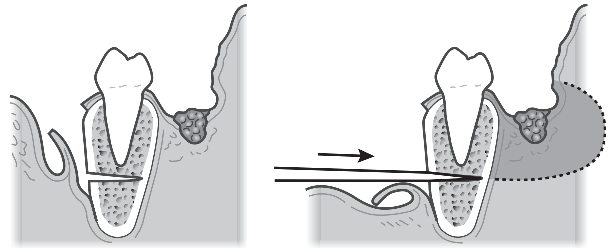

Figure 44.21 Three-dimensional excision of the sublingual gland including the adjacent alveolar bone.

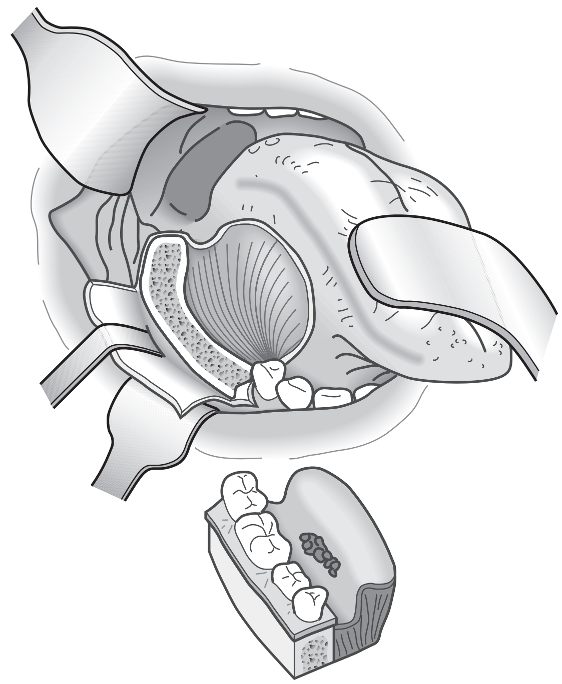

Figure 44.22 Excised specimen with clear margins and residual defect.

major problems. Both of these nerves can be reconstructed by grafting at the time of the tumour excision, although because of the poor prognosis of such tumours, this is often not executed.

SURGERY OF THE MINOR SALIVARY GLANDS

Glands in the mobile soft tissues

Minor gland biopsy

The surgeon is sometimes asked to provide specimens of minor glands to confirm the diagnosis of Sjogren's syndrome. The biopsy should be taken from the inner aspect of the lower lip. The incision should be made in the vertical plane just through the mucosa. The lip is then retracted

and the assistant places a finger on the outer aspect of the lip, everting the submucosa into the wound. A minimum of three minor glands are identified and excised. They can be seen as pale yellow glistening 'grains of rice' within the connective tissue of the submucosa. Haemostasis is obtained and the mucosa closed with a single resorbable suture.

Tumour excision

When a patient presents with a mobile mass in the submucosa of the mobile soft tissues, the assumption should be that it is a neoplasm until proved otherwise. Many of these will be benign pleomorphic adenomas and open incisional biopsy would result in tumour seeding into the adjacent tissues. For this reason, a simple excision biopsy of the minor gland is the appropriate management for all such masses. The excision is performed in the extracapsular plane and even for tumours that prove to be malignant, this will often prove to be sufficient as these tumours do not infiltrate the gland capsule until late in their development.

Palatal gland surgery

The detailed pathology of masses and ulcers arising on the hard palate prior to surgery is all important and an incisional biopsy is essential before definitive surgery is undertaken. The differential diagnosis of persistent ulcers arising on the hard palate includes acute necrotizing sialometaplasia (Figure 44.23), adenoid cystic carcinoma, squamous cell carcinoma and antral carcinoma. The definitive management of these conditions will all be very different. Even a small adenoid cystic carcinoma will involve at least a partial maxillectomy, whereas a pleomorphic adenoma requires no more than excision with a narrow margin of mucosa and dissection in the subperiosteal plane. Low-grade mucoepidermoid tumours will require a local palatal fenestration and a 1-cm mucosal margin.

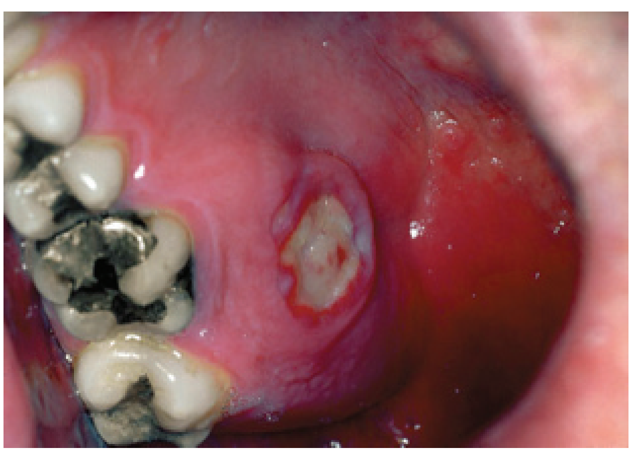

Figure 44.23 Acute necrotizing sialometaplasia.

OPERATION FOR EXCISION OF BENIGN TUMOURS

This technique is appropriate for pathology such as pleomorphic adenoma (Figure 44.24), neurofibromas or haemangiomas. Although the operation can be readily performed under local anaesthesia, it is often kinder to use a general anaesthetic as bleeding from the hard palate can be distressing for a conscious patient. In this situation, the patient is positioned supine on the operating table with a sand bag under the shoulders and a head down tilt of the table. The surgeon sits at the head of the table. The palate is infiltrated with 2% lignocaine with 1:80,000 epinephrine (adrenalin).

The mucosal margin is mapped out with ink (Figure 44.25). A 5-mm margin is adequate. The incision is made down to the bone using a fine cutting diathermy needle. The specimen is then freed in the subperiosteal plane with a Howarth's periosteal elevator or Mitchell's trimmer.

Although benign, long-standing pleomorphic adenomas can result in pressure resorption of the underlying palatal bone and there may be a concavity in the palate (Figure 44.26). However, it is important to realize that such benign tumours will never penetrate the periosteum.

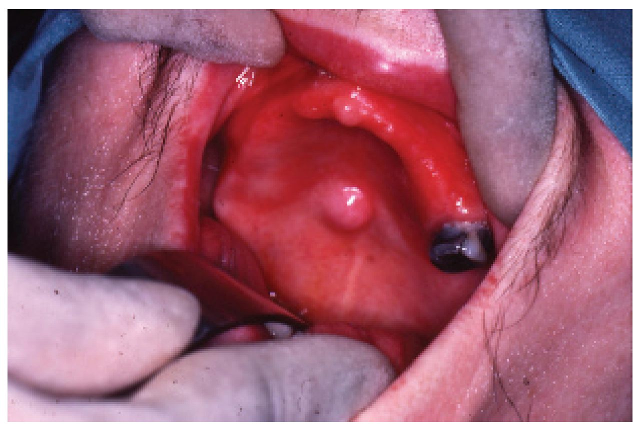

Figure 44.24 Benign tumour arising on the hard palate.

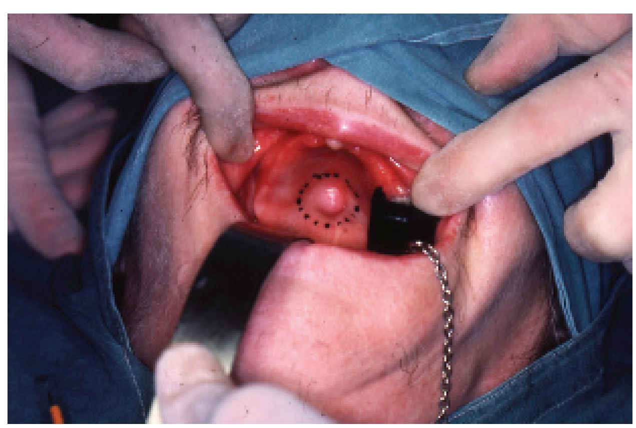

Figure 44.25 Incision marked out with 5-mm margins.

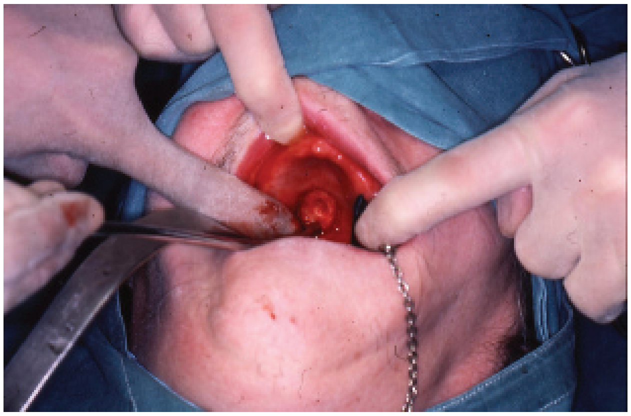

Figure 44.26 Following the subperiosteal dissection the concavity of the palatal bone due to pressure resorption is seen.

Figure 44.27 A small Whitehead's varnish pack has been applied to protect the healing area.

The defect may be left to heal by secondary intention, although it should be protected by a Whitehead's varnish pack or by a preformed acrylic appliance, relieving the area of resection in order to accommodate some periodontal pack as a dressing (Figure 44.27). The pack or plate should be retained for about 10 days by which time the area will be granulating. Some large defects may take several weeks to heal and in such cases a removable plate should be utilized to protect the area. The plate must be kept scrupulously clean and removed and rinsed after all meals. A chlorhexidine mouth wash should be used to rinse when the plate is removed for cleaning.

OPERATION FOR LOW-GRADE MALIGNANT TUMOURS

For all low-grade malignant tumours, palatal fenestration with a 1-cm mucosal margin is indicated. The operation is performed under general anaesthetic with the patient and surgeon positioned as mentioned earlier.

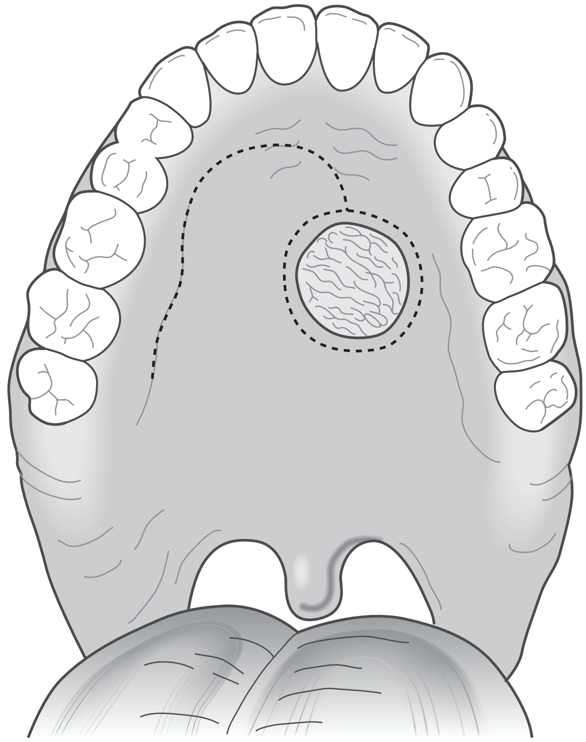

Figure 44.28 Palatal rotation flap.

Following mapping of the 1-cm mucosal margin and the diathermy incision, a dental bur is used to cut through the palatal bone at the margins of the incision. The excision specimen can then be gently elevated and any underlying structures, such as the nasal septum or antral wall, can be divided with heavy scissors.

Whenever possible, an immediate reconstruction should be undertaken. For small defects, a palatal rotation flap may be suitable. The palatal flap should be mapped out parallel to the dental arch and is based on the greater palatine artery. In order to avoid damage to this vessel, the incision should stop 1 cm anterior to the greater palatine foramen (Figure 44.28, see also Chapter 17).

The flap is raised in the subperiosteal plane and rotated to cover the fenestration defect. It needs to be firmly sutured into position with non-resorbable sutures as there is a tendency for the flap to pull back to its anatomical position (Figure 44.29). The sutures should be retained for 2 weeks. The donor site defect is covered with a Whitehead's varnish pack.

For more lateral palatal defects, a buccal advancement flap used to close oro-antral communications can be utilized. The flap must be broad-based and it should extend to the full depth of the buccal sulcus (Figure 44.30).

The periosteum on the deep aspect of the flap is incised with a sharp blade parallel and close to the base of the flap. This relieving incision through the unyielding periosteum allows the flap to be advanced on to the palate (Figure 44.31).

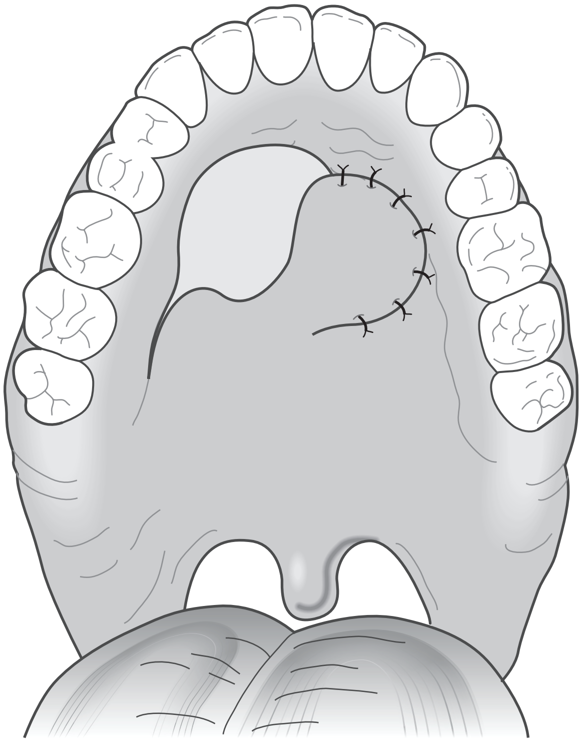

Figure 44.29 Closure of palatal defect.

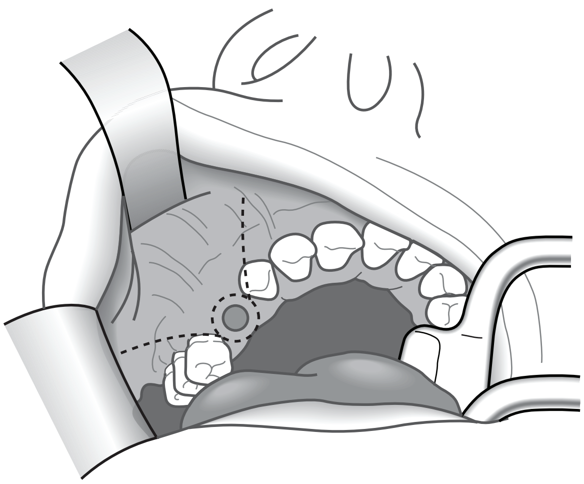

Figure 44.30 Outline of buccal advancement flap.

Great care must be taken not to incise beyond the periosteum as a button hole through the flap will compromise the blood supply. It is also important to ensure that the periosteal relieving incision extends to the full width of the flap. Failure to do this results in the flap failing to advance as it remains tethered by the unyielding periosteum.

The palatal margins of the fenestration defect must be undermined and the mobilized buccal flap is meticulously sutured to the palatal mucosa with everting mattress sutures. Non-resorbable sutures must be used and they should be maintained for 2 weeks to ensure healing (Figure 44.32).

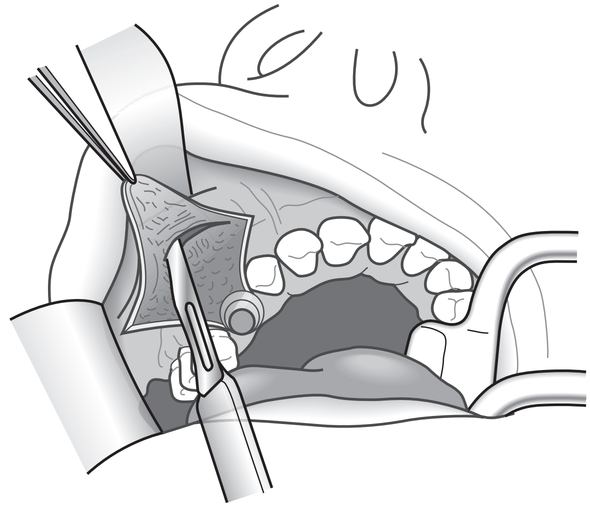

Figure 44.31 Periosteal relieving incision.

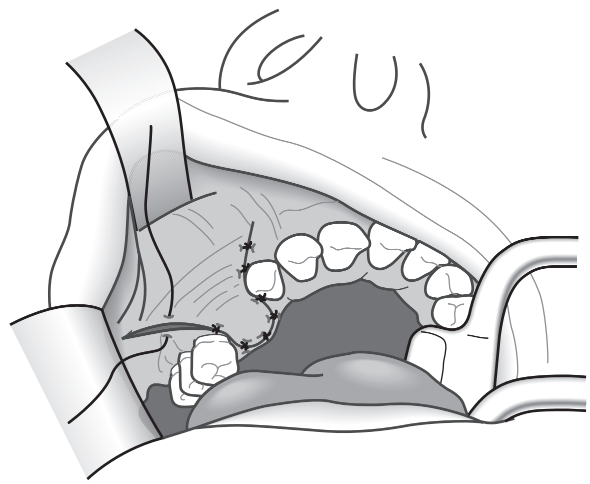

Figure 44.32 Closure of palatal defect using buccal advancement flap.

Posterior full-thickness palatal defects are conveniently closed with buccal fat pad flaps as described in Chapter 17. For central palatal defects, bilateral buccal fat pads can be used.

SURGERY FOR HIGH-GRADE MALIGNANT TUMOURS

For all aggressive malignant tumours, particularly adenoid cystic carcinomas, partial or total maxillectomy followed by radiotherapy including the skull base is indicated. When a maxillectomy has been undertaken, the defect is reconstructed with a vascularized hip graft (Chapter 28) or a fibular flap (Chapter 27). An alternative is to reconstruct the defect with an implant retained obturator (Chapter 14).

Top tips

- When removing submandibular stones, it is important to irrigate the duct in order to remove any 'gravel' remaining in the duct system.
- When excising the submandibular gland, the lingual nerve must be fully visualized and the parasympathetic fibres tethering the nerve to the gland must be severed in order to free the gland.
- The only effective treatment for a ranula is excision of the related gland which is nearly always the sublingual gland. Occasionally, the submandibular gland can be responsible.
- The majority of sublingual gland tumours are malignant and wide surgical excision and post-operative radiotherapy are essential.
- Pre-operative diagnosis of a palatal gland tumour is essential. Benign tumours require local excision with a very narrow cuff of normal mucosa, low-grade tumours require palatal fenestration and high-grade tumours require radical maxillectomy.

SUGGESTED READINGS

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45

Management of stones and strictures and interventional sialography

MICHAEL P ESCUDIER and JACQUI E BROWN

CONTENTS

MANAGEMENT OF STONES AND STRICTURES

Sialolithiasis accounts for approximately 50% of major salivary gland disease. The incidence of symptomatic sialolithiasis is between 27.5 and 59 cases per million population per year.

The presence of a salivary calculus usually results in mechanical obstruction of the salivary duct, causing repeated swelling during meals, which can remain transient or be complicated by bacterial infections. Until recently, recurring episodes necessitated open surgery with calculi that lay in the proximal duct or gland requiring sialoadenectomy despite its attendant risks (see Chapters 44 and 46).

During the past 18 years, minimally invasive and nonsurgical techniques for the removal of salivary calculi have been developed. The basis for this approach resides in the fact that salivary glands have been shown to have significant reparative potential. Scintigraphic studies before and after removal of a submandibular calculus have shown that the gland can recover. In addition, the duration of obstructive symptoms does not influence the amount of recovery observed (Figure 45.1a and b).

While a variety of techniques have been investigated, those which have progressed beyond the initial trials and remain in clinical practice include basket retrieval and microforceps retrieval, both of which can be performed under either endoscopic or radiological control. Intra- and extracorporeal shock wave lithotripsies have also assumed a continuing role, as has gland-preserving surgery for submandibular calculi and an endoscopically assisted form for parotid stones.

LITHOTRIPSY

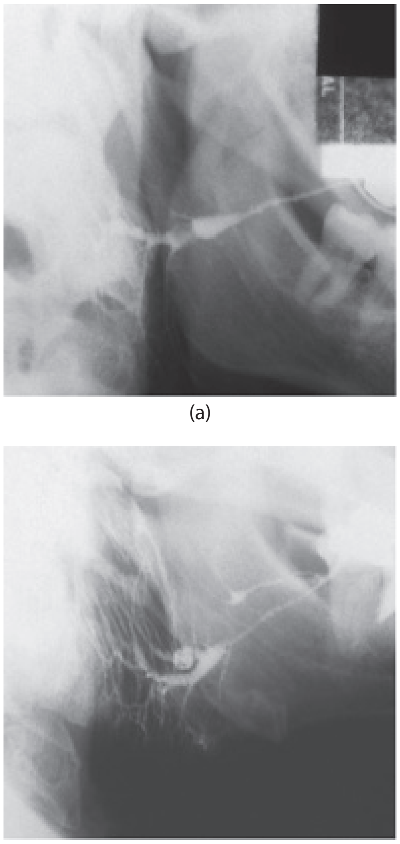
Following the successful introduction of lithotripsy for renal calculi in the 1980s, the technique has been applied to several other areas of the body including, with the development of specialized machines, the salivary glands.

Extracorporeal shock wave lithotripsy

At the present time, the devices which generate the shock wave are either piezoelectric (Piezolith 2501; Richard Wolf, Knittlingen, Germany) or electromagnetic (Minilith; Storz Medical, Tagerwilen, Switzerland) (Figure 45.2).

Patient selection

A number of selection criteria have been developed for this technique (Table 45.1), which have led to it principally being used in the management of fixed parotid stones.



(a)

(b)

Figure 45.1 (a) Pre-treatment sialogram showing presence of obstruction associated with poor ductal architecture. (b) Post-treatment sialogram showing improvement in glandular architecture.

Figure 45.2 Salivary lithotripter with patient in treatment position for a parotid stone.

In addition, where present, acute sialoadenitis must first be treated with antibiotics.

Table 45.1 Selection criteria.

Inclusion criteria	Exclusion criteria
Symptomatic disease	Stones amenable to intra-oral surgery
Exact sonographic location of concretions	Stones amenable to radiologically/ endoscopically guided basket retrieval
	Calculi not readily identifiable by ultrasound
	Patients with blood dyscrasias or haemostatic abnormalities
	Patients who are pregnant
	Patients who have undergone stapedectomy or ossicular repair

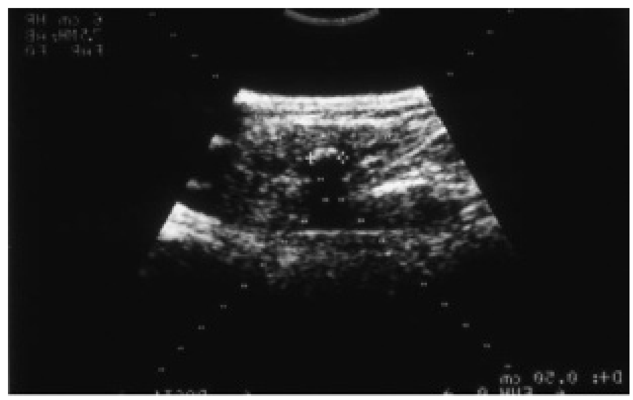


Figure 45.3 Ultrasound image showing large intra-glandular parotid stone with posterior acoustic shadow.

Technique

Treatment is performed on an outpatient basis. After ultrasonographic localization of the stone (Figure 45.3), shock waves are delivered to a maximum per visit (3000 piezoelectric, 7500 electromagnetic). In general, a series of three sessions separated by 4–12 weeks are required.

Following successful fragmentation, pieces of calculus migrate distally and exit the duct either spontaneously (Figure 45.4) or as a result of adjuvant measures (massage, sialogogues) or techniques (dilatation of ostium, papillotomy, endoscopic or basket retrieval).

Common, reversible complications include mild swelling of the gland (60%–70%), self-limiting ductal haemorrhage (40%–55%) and petechial skin haemorrhage (40%–55%), while acute sialoadenitis is rare (1.5%–5.7%).

Outcome

Success rates are generally expressed in terms of cure (stone and symptom free), partial success (residual stone without symptoms) and failure (residual stone and symptoms).

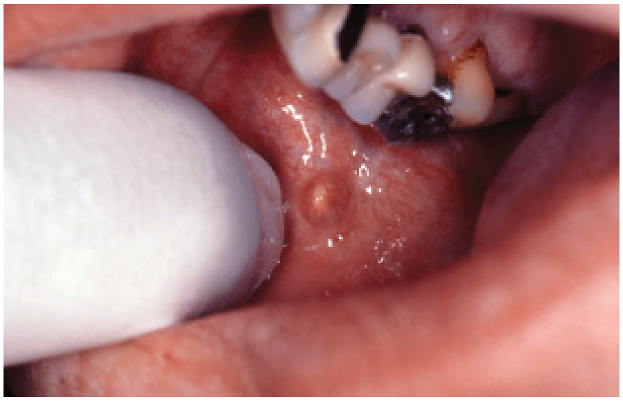


Figure 45.4 Fragments of parotid calculus at parotid duct ostium following lithotripsy.

In the five published series with over 100 cases, the overall cure rates vary from 29% to 63%, whereas 56.7% to 100% are rendered stone or symptom free (Table 45.2).

The cure rate is significantly better (34.2%–69.3%) for parotid (Table 45.3) than for submandibular (29.0%–41.1%) stones (Table 45.4). Similarly, the percentage of patients with neither stones nor symptoms is higher for parotid cases (68.6%–100%) than for submandibular cases (56%–100%).

In a long-term (10-year) follow-up study of submandibular stones, one-third of patients remained stone free, one-third still had residual fragments but were symptom free and one-third required additional intervention.

Predictive factors

The cure rate for parotid stones is significantly greater than that for submandibular stones. Several authors have reported an association between the size of the stone and the stone-free rate, while others have not. This association is not seen repeated in the case of partial success.

Intracorporeal shock wave lithotripsy

The development of micro-endoscopes has enabled sialoendoscopy for both diagnostic and interventional purposes. In intracorporeal shock wave lithotripsy, a lithotripsy probe is passed along the salivary duct, under endoscopic guidance, to be adjacent to or in contact with the stone surface.

Initial studies in this area centred on the use of electrohydraulic and pneumatic lithotripsy. Electrohydraulic intracorporeal lithotripsy (Calcitript; Storz Medical) was successful in fragmenting the calculus in 60%–70% cases. A flexible endoscope together with the shock wave probe were introduced into the duct and advanced until the probe was 1 mm away from the sialolith. The shock waves were generated by a sparkover at the tip of the 600-µm probe. Pneumobalistic lithotripsy used a LithoClast (Electro Medical Systems,

Table 45.2 Overall success rates for salivary lithotripsy (minimum 100 cases).

Study	Year	Lithotripter	No. of cases	Cured (%)	Partial success (%)	Failure (%)
Kater	1994	Electromagnetic, Minilith	104	38.4	18.3	43.3
Katz	1998	Electromagnetic, Minilith	200	63.0	34.0	3.0
Escudier	2003	Electromagnetic, Minilith	122	33.0	35.0	32.0
Zenk	2004	Piezoelectric, Piezolith 2500	197	29.0	71.0	0.0
Capaccio	2004	Electromagnetic, Minilith	322	45.0	27.4	27.6

Table 45.3 Success rates for parotid stone lithotripsy (minimum 24 cases).

Study	Year	Lithotripter	Parotid cases	Cured (%)	Partial success (%)	Failure (%)
Kater	1994	Electromagnetic, Minilith	29	48.30	10.3	41.4
Ottaviani	1997	Electromagnetic, Minilith	24	58.30	41.7	0
Iro	1998	Piezoelectric, Piezolith 2500	76	50.00	26.3	23.7
Escudier	2003	Electromagnetic, Minilith	38	34.20	44.7	21.1
Capaccio	2004	Electromagnetic, Minilith	88	69.30	27.3	3.4

Table 45.4 Success rates for submandibular stone lithotripsy (minimum 75 cases).

Study	Year	Lithotripter	Submandibular cases	Cured (%)	Partial success (%)	Failure (%)
Kater	1993	Electromagnetic, Minilith	75	34.7	21.3	44
Ottaviani	1997	Electromagnetic, Minilith	56	41.1	25	33.9
Escudier	2003	Electromagnetic, Minilith	84	32.1	30.9	37
Zenk	2004	Piezoelectric, Piezolith 2500	197	29.0	71	0
Capaccio	2004	Electromagnetic, Minilith	234	35.9	27.4	36.7

Nyon, Switzerland). This equipment consists of a central unit, connected to a compressed air source, producing a pressure of 3 bar at the handpiece. The handpiece generated ballistic energy and converted it into shock waves which were applied directly to the stone via the probe. Using this equipment, in the working channel of a 2.1-mm endoscope, stone-free rates of up to 60% were reported. However, both techniques have been abandoned because of the high risk of unwanted effects such as ductal perforation and nerve damage.

Later studies investigated the use of laser lithotripsy and several systems have been evaluated in vitro and in vivo. Unfortunately, the Nd-YAG (1064 nm; LASAG-AG, Belp, Switzerland) and Alexandrite (755 nm; Dornier Medizintechnik, Germany) lasers were unsuitable because of inadequate fragmentation. In the case of the Exicmer laser (308 nm; Technolas Laser Technologie, Germany), stone-free rates of up to 91.6% were reported, but were associated with a high rate of ductal perforation and its use in humans is inadvisable. The Rhodamine-6G-Dye-laser (595 nm; Lithoghost, Telemit-Company, Munchen, Germany), however, proved successful. This had the added advantage of using a novel spectroscopic feedback technique which analysed the reflected laser light to distinguish between calculi and soft tissue, so minimizing damage to the duct. Its use was associated with complete removal of stones in 46% of cases after between one and three treatment sessions.

All of these techniques required a papillotomy to enable the endoscopically controlled equipment to access the ductal system. In addition to this, the techniques often require expensive equipment and are relatively time-consuming for the success rates achieved. As a result, intracorporeal shock wave lithotripsy is currently of limited clinical importance.

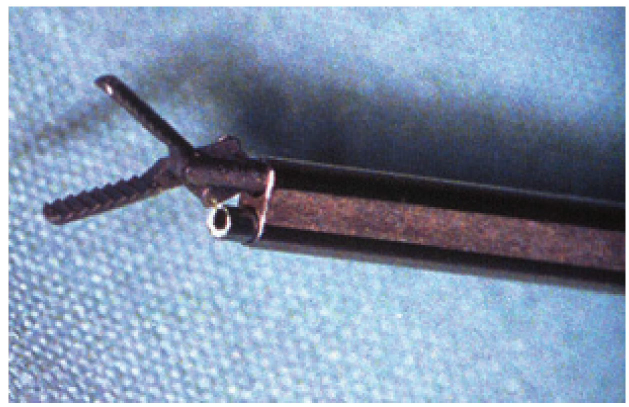


Figure 45.5 Salivary endoscope with microforcep *in situ*.

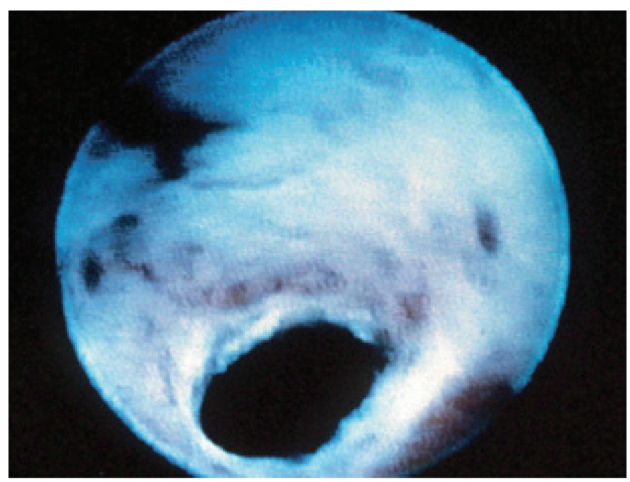


Figure 45.6 Pre-operative endoscopic view of salivary duct.

ENDOSCOPIC RETRIEVAL

The initial attempts at endoscopically guided stone retrieval used flexible endoscopes. Unfortunately, these were difficult to manoeuvre, fragile, provided only poor images and were difficult to sterilize. This situation improved with the use of semi-rigid endoscopes, although the diameter of the device (relative to the lumen of the duct) resulted in difficulty in progressing along the duct and ductal tears. Rigid endoscopes proved most successful (Figures 45.5 and 45.6) and have developed progressively from the initial 2.7-mm-diameter arthroscopes, which required a papillotomy to facilitate ductal entry, to one (Marchal sialoendoscope; Karl Storz, Tuttlingen, Germany) which

measures 1.3 mm in diameter and contains an optic fibre of 6000 pixels, a rinsing channel of 0.25 and a working channel of 0.65 mm for instrumentation.

Clinical and radiographic assessment of prospective cases is essential, as exclusion criteria for the technique include narrow ducts, ductal strictures and intra-parenchymal location of stones. In addition, acute sialoadenitis should be treated with antibiotics prior to intervention.

In the technique, the endoscope is introduced into the ductal system and progressed until the sialolith is identified. The stone is then removed using suction, basket or microforceps. If the stone is large, then fragmentation by microforceps or laser lithotripsy is required to facilitate its removal. While the first is time-consuming, the latter is associated with the previously detailed problems associated with laser lithotripsy, although further advances may address these issues. Post-operative antibiotics have been advocated, as have stenting of the duct with a 2-mm polyethylene tube, although the value of the latter is questionable.

Overall success rates of more than 80% have been reported. However, the success rates are directly related to the size of the stone with one study reporting a 97% cure rate for stones smaller than 3 mm and 35% for those larger than 3 mm.

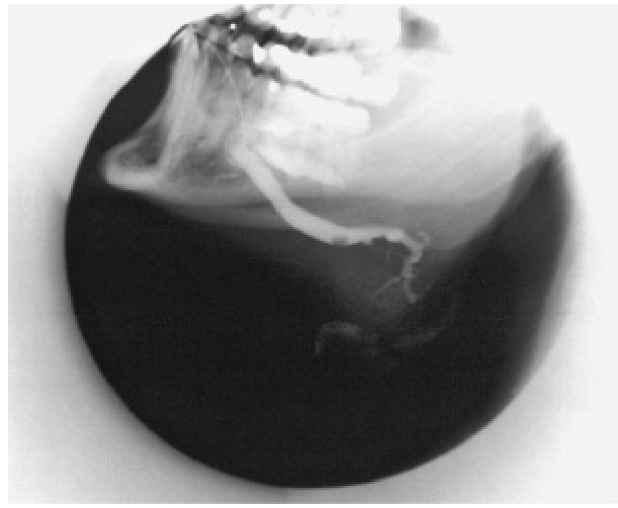


Figure 45.7 Submandibular sialogram showing a stone in the proximal part of the main duct.

Figure 45.8 Parotid sialogram showing two diffuse strictures, one at the entry to the hilum of the gland and one more distally placed near the division of the main duct with a secondary branch.

INTERVENTIONAL SIALOGRAPHY

Introduction

Radiological techniques have been used to investigate the salivary glands since 1900, when Charpy first described the injection of mercury into the salivary ducts in order to demonstrate salivary gland anatomy. Sialography is still widely practised in the diagnosis of obstruction, sialoadenitis and Sjogren's syndrome. It remains the most sensitive method for detecting salivary stones and strictures within the ductal system of the major salivary glands.

In recent years, its role has been developed and extended into interventional radiological techniques in the salivary ducts to treat ductal obstruction. Interventional sialography has thus become one of several new minimally invasive techniques within the armamentarium of the clinician seeking to treat one of the most common salivary gland complaints, salivary gland obstruction, without resorting to surgery.

Salivary gland obstruction may be due to either extra-ductal or intra-ductal causes. Intra-ductal causes are most common and principally include salivary calculi and duct stenoses. A recent analysis of the incidence of salivary ductal obstruction in a series of more than 1300 sialograms undertaken for patients with obstructive symptoms showed an obstruction in 64% of the investigated cases, of which 73% had salivary calculi and 23% had a stricture. This highlights the greater incidence of stones (Figure 45.7), but also illustrates the very real problem of salivary duct stenosis (Figure 45.8). This study also showed that duct strictures were far more common in the parotid glands of middle-aged women and may be, in around 7%, bilateral.

Interventional sialography has developed methods for treating both eventualities using ideas taken from other areas of intervention. Ductal calculi may be extracted by capture with devices such as small collapsible Dormia baskets, where these have been used to extract biliary and ureteric stones (Figure 45.9). These are introduced into the ductal system within fine catheters and deployed to capture the stone once they have been positioned around or beyond the stone. Salivary duct strictures are amenable to dilatation by balloon catheters in a similar way to vascular stenoses or strictures developing within the ureteric system or within haemodialysis fistulas.

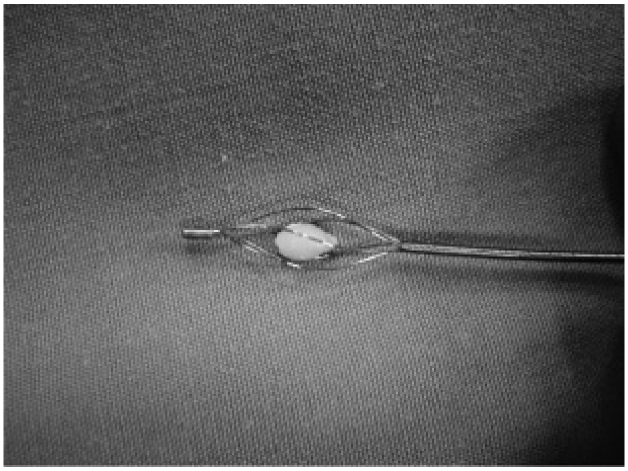


Figure 45.9 A Dormia basket containing a stone.

Case selection and patient preparation for interventional sialography

Sialography and ultrasound examinations form the prerequisite imaging for case assessment prior to intervention in the salivary ducts. Sialography successfully distinguishes salivary calculi from strictures, and ultrasound successfully distinguishes stones from soft mucous plug debris, since a stone will show a bright area within the salivary duct with an acoustic shadow behind it, whereas soft debris shows a similar appearance but no acoustic shadow.

Sialography and ultrasound also localize a stone or stricture, give its dimensions, identify multiple stones and help to identify if a stone is mobile. Stones within the main parotid and submandibular ducts are amenable to extraction using this technique, but cannot normally reach stones within the submandibular hilum since the Dormia basket cannot pass beyond the genu of the duct. Mobility of the stone on the pre-operative sialogram is a good prognostic factor, since it indicates that the stone is not fixed or fibrosed to the duct wall, which would prevent its extraction. Sialograms also allow assessment of the condition of the proximally placed gland. However, importantly, only sialography allows one to assess the width of the duct running distally from a stone to the duct orifice. This is crucially important if the stone is to be withdrawn down this distal duct, since there must not be too great a mismatch between the size of stone and the duct. It would be sensible to avoid extraction of stones more than 25% greater in width than the width of the narrowest section of the distal salivary duct. Care should be exercised in case selection at this point – if a large stone is captured in a basket but is too large to be withdrawn down the relatively narrow duct, then the basket will become impacted in the proximal duct and will almost certainly require surgical release. This is an important complication, which can be avoided with sensible treatment planning. Larger and very proximal stones are best treated first by extracorporeal shock wave lithotripsy to break down the stone into more manageable pieces. If a stricture is identified distal to the stone to be removed, then planning will be required to dilate this area of duct stenosis prior to stone extraction, using an angioplasty balloon.

Sialography also plays a key role during intervention. During interventional sialography, the pre-operative sialogram is used to confirm the exact nature and location of the obstruction and to guide the placement of the interventional tool in relation to the obstruction.

One noted advantage of minimally invasive techniques has been the ability to carry out treatment under local anaesthesia, avoiding conventional surgery under general anaesthetic and therefore enabling treatment of patients with more complex medical conditions that might otherwise preclude intervention. Treatment under local anaesthesia is additionally more time-efficient, does not require inpatient hospital admission and is generally associated with lower morbidity.

Local anaesthesia is achieved for intervention in the parotid gland by infiltrating the cheek around the Stenson's duct papilla with 2% lignocaine and by instilling local anaesthetic into the parotid duct to create some topical anaesthesia of the duct wall. For interventional procedures in the submandibular ductal system, an inferior nerve block accompanied by a lingual nerve block is very effective.

Radiologically guided salivary stone extraction

A technique for stone extraction under fluoroscopic radiological guidance was first demonstrated by Briffa and Callum in 1989, and described the extraction of a small stone from the submandibular duct. An angioplasty balloon catheter was inserted into the salivary duct, the balloon slid proximal to the stone and inflated, then withdrawn to the orifice of Wharton's duct, trapping the stone and drawing it up to the orifice. Following this, similar procedures were reported using interventional catheters normally used for vascular work, such as vascular snares and graspers to trap salivary stones and extract them from the salivary ducts, but most of these subsequent case reports and small case series have reported greatest success with Dormia baskets. In these papers, success rates of between 60% and 100% have been reported.

The technique for stone removal from the parotid and submandibular ducts using a Dormia basket technique under fluoroscopic x-ray guidance and local anaesthesia is a relatively simple procedure with a high success rate and low morbidity. Following treatment planning, on the basis of clinical examination and pre-operative imaging, the patient is given a suiTable local anaesthetic and a sialogram is performed. The duct orifice is gently dilated with lachrymal duct and Nettleship dilators to sufficient diameter to receive a 3-French Dormia basket catheter. The Dormia basket catheter is inserted in the closed position and guided into position under radiological control. The catheter tip is normally required to pass beyond the stone, into the proximal salivary duct (Figure 45.10). Once in this

Figure 45.10 Inter-operative submandibular sialogram showing the basket inserted beyond the stone.

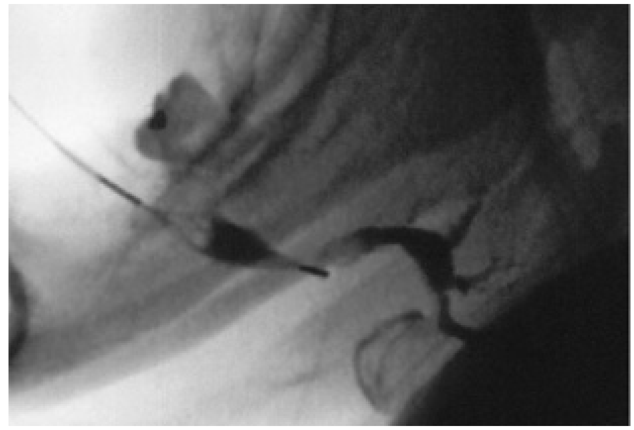


Figure 45.11 Inter-operative sialogram showing the basket, with stone trapped within it, being withdrawn forward to the orifice of Wharton's duct.

Figure 45.12 Papillotomy is performed to release a stone, trapped in a Dormia basket, from the submandibular duct.

position, the basket is opened and withdrawn across the stone to capture it. This can be confirmed under imaging control (Figure 45.11). The stone is captured and then withdrawn to the papilla, where a small papillotomy incision is often needed to deliver the stone (Figure 45.12). An immediate post-operative sialogram is helpful to check for any residual stones.

Radiologically guided balloon ductoplasty

Salivary duct strictures are believed to develop secondary to previous duct wall irritation and inflammation, as may follow the presence of a stone, local trauma or infection. They are normally found within the main excretory duct and 75% are located in the main duct of the parotid gland, making these far more common in this situation than in the submandibular system. A recent study also showed these to be more common in middle age and in women.

This technique offers a non-surgical option for those patients developing symptoms of obstruction as a result of duct stenosis, and for relieving strictures distal to a stone prior to stone extraction. Angioplasty balloons are available in widths suiTable for dilation of salivary ducts, which normally range in diameter from 1 to 2 mm. The aim of the procedure is to dilate the duct to slightly greater than its normal calibre and to break the circumferential bands of fibrous tissue forming within the duct wall.

The patient is prepared in the same way as for stone extraction, using a pre-operative sialogram to identify the nature and position of the stenosis. A local anaesthetic is given, the duct orifice dilated manually with dilator instruments and a pre-operative sialogram performed. Immediately, without moving the patient, the balloon catheter is inserted into the duct. The lateral sialographic view is used to guide the balloon catheter into position along a guide-wire which, together with the balloon catheter, is inserted into the duct orifice and moved gently but firmly down the duct until it passes through the most proximal area of strictured duct. The balloon is positioned centrally within the stricture and inflated fully for several minutes to ensure good dilation (Figure 45.13). Tight stenosis may require several inflations. The balloon is then deflated fully and withdrawn forward to the next, more distal stricture if present. The procedure is repeated, if necessary, until all the stenoses are satisfactorily dilated. A post-operative sialogram is used to check satisfactory duct calibre before the duct is finally irrigated.

Post-operative care

Following a salivary intervention, the patient is advised to keep well hydrated and to stimulate the gland with sialogogues and self-massage to ensure that the operative site

Figure 45.13 Post-operative view following balloon ductoplasty for two strictures of the parotid duct (see Figure 45.7 for pre-operative appearance). Note the filling defect representing mucous plug against the inferior duct wall within the dilated hilum.

remains patent. Intervention in the salivary ducts is normally accompanied by some degree of local oedema, particularly following balloon ductoplasty. The effect of the local oedema may be to cause compression of the duct and a temporary return of gland swelling, especially at mealtimes. The patient needs to be counselled to expect this for several days. Post-operative antibiotic prophylaxis is not always needed, but may also be appropriate if infection is suspected.

Value of interventional sialography

To date, our experience of this technique at this centre has included 443 interventional radiologically guided salivary gland treatments for benign obstruction; 252 for salivary stone extraction and 194 balloon ductoplasties. Patients included 190 males and 253 females ranging in age from 8 to 85 years, with an average age of 48 years.

In 252 cases of salivary stones, 96 (38%) were in the parotid glands and 156 (62%) in the submandibular glands, which is a rather different distribution to that normally quoted (normally around 80%–90% in the submandibular duct system), but probably reflects a different patient group who are keen to avoid surgery, especially a superficial parotidectomy, which carries the risk of facial nerve palsy. Successful stone clearance was achieved in 77% (194/252) of the study group, partial clearance was achieved in 8.3% (that is, some but not all stones were removed) and in the remaining 14.7% (37/252) the procedure failed to remove the intended stone. This was primarily due to an immobile stone (adherent to the duct wall) or due to the inability to capture the stone due to an unfavourable position within a secondary duct or side branch.

A total of 194 salivary duct strictures were diagnosed and treated, generally with a higher average age of 51 years and showing a distinct predilection for females (male/female ratio = 1:1.87). Balloon ductoplasty achieved elimination of duct strictures in 78.4% (152/194), whereas 11.8% (23/194) showed some residual stenosis on post-operative sialogram. The procedure was not completed successfully in 5.2% (10/194) of the group, primarily due to the density of the stenosis which prevented passage of the balloon. Degree of final dilatation was not recorded in nine patients (4.6%).

CONCLUSION

Increased awareness has led to a demand from the public for less invasive surgical options to treat conditions such as salivary gland obstruction. Conservative management with minimally invasive techniques has come about through technological advances across a range of fields, with many techniques borrowed from other areas of medicine and offers a low-morbidity treatment option. Radiology has followed a similar path and now offers a choice of radiologically guided techniques for treating both salivary stones and strictures. These techniques compliment other new modalities such as extra- and intracorporeal lithotripsy, sialoendoscopy and limited-access surgery, such that they may be used in isolation or as part of a combined multimodal approach to treatment.

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46

Facial nerve dissection and formal parotid surgery

JOHN D LANGDON

CONTENTS

PRINCIPLES AND JUSTIFICATION

The parotid gland is subject to acute ascending bacterial infection from the oral cavity. Provided the infection is controlled with antibiotics, the gland will usually make a complete functional recovery. In a few cases, the gland becomes chronically infected with recurrent acute flare-ups leading ultimately to sialectasis and duct changes. Chronic infection is particularly common when salivary flow rates are reduced, such as in Sjogren's, syndrome or following radiotherapy. In this situation, it is best to remove the superficial lobe of the parotid and to tie off the main duct as far distally as possible. It is not usually necessary to remove the deep lobe, which accounts for only 20% of parotid mass, as this undergoes spontaneous atrophy following superficial lobectomy and duct tie.

Calculi in the parotid duct system are uncommon. The majority impact is at the parotid papilla and is readily released by papillary dilatation with lachrymal probes or fine bougies. Failing this, a papillotomy can be performed under local anaesthesia. Calculi in the intra-glandular part of the duct are usually located at the junction of the main duct and the first-order tributaries, the stone mimicking a staghorn calculus is seen in the renal pelvis (see also Chapter 45).

The majority of salivary tumours (75%) are found in the parotid gland. The overwhelming majority present as slow-growing painless masses within the parotid capsule. Of these tumours, 85% will be benign, mostly pleomorphic salivary adenomas. When skin fixation, ulceration or fungation, facial nerve weakness or lymphatic metastasis is present, and the tumour is clearly malignant. The absence of these signs does not exclude malignancy. The majority of malignant parotid tumours are clinically indistinguishable from benign tumours.

In recent years, there has been a move to more conservative procedures and in particular extracapsular dissection. However, it remains essential that any surgeon dealing with parotid pathology remains competent in the technique of facial nerve dissection and formal parotidectomy. These techniques are required when operating for malignancy, tumour recurrence (benign and malignant) and deep lobe tumours.

PRE-OPERATIVE INVESTIGATIONS

Routine surgical biopsy is not indicated. The majority of intrinsic parotid masses will be pleomorphic adenomas. These tumours are tense and poorly encapsulated. Rupture, either at the time of biopsy or surgery, leads to widespread spillage of clumps of cells resulting in multiple recurrences which may be very difficult to control. If the tumour remains intrinsic within the parotid at the time of surgery, the exact histological diagnosis is unlikely to influence the definitive surgical procedure. However, if the tumour is obviously malignant and has extended beyond the anatomical boundaries of the parotid, open surgical biopsy is indicated.

Fine needle aspiration biopsy has been widely advocated in the pre-operative diagnosis of parotid masses. Although it is safe, oral pathologists find it difficult to make a definitive diagnosis based on a few aspirated clumps of cells, because the architecture of the tumour is lost, many parotid tumours are heterogenous in appearance and the aspirated sample may not be representative. Furthermore, there is the risk of sampling error although this is reduced when using ultrasound guidance. The newer technique of fine needle core biopsy, particularly when performed using ultrasound guidance, offers hope of more accurate diagnosis.

IMAGING

Conventional sialography is the investigation of choice in chronic inflammatory disease, autoimmune disease and duct obstruction. The post-stimulation emptying film is most valuable as it is a good measure of function and will often determine if surgical excision is indicated.

For the imaging of parotid masses, either computed tomography (CT) scanning or magnetic resonance imaging (MRI) are equally useful. MR imaging avoids the use of ionizing radiation, but CT is better tolerated by patients. Both techniques give a good anatomical image of the region, but can neither reliably demonstrate the plane of the facial nerve nor confidently distinguish intrinsic malignant tumours from benign.

Ultrasound imaging is indicated in acute parotid swellings as it will reliably demonstrate obstruction and collections of pus. In chronic infection, it will show advanced sialectasis and duct dilatation. It will also characterize calculi if they are calcified. Warthins tumours are echo poor and show posterior acoustic enhancement whereas pleomorphic adenomas are echogenic.

PAPILLOTOMY

Although readily performed under local anaesthesia, the operation must be performed carefully in order to avoid subsequent stricture formation. A fine metal probe is passed through the papilla into the parotid duct. Using the probe as a guide, one blade of a pair of sharp pointed scissors is inserted into the duct and the wall of the duct is laid open. The cut should be extended posteriorly until the point of the scissors enters the dilated part of the duct proximal to the site of obstruction. A 6-0 resorbable suture is used to sew the cut edge of the duct lining on to the adjacent mucosa of the cheek. This results in the formation of a funnel-like opening of the duct on to the cheek and avoids subsequent stricture formation.

SURGICAL REMOVAL OF PAROTID STONES

Anaesthesia

The operation is performed under general anaesthesia. The patient is positioned supine with moderate neck extension and the head turned away from the operative side. Head-up tilt on the table helps to prevent venous congestion and ooze. Some anaesthetists are willing to moderately lower the blood pressure, which reduces arteriolar and capillary bleeding.

The hair in front of the ear is either shaved or gathered into a tuft which can be taped down on to the skin of the cheek. The area is infiltrated with conventional dental local anaesthetic containing 2% lignocaine hydrochloride and 1:80,000 epinephrine (adrenaline). The external auditory meatus is plugged with a small piece of Vaseline-impregnated tulle to prevent blood entering the meatus and irritating the drum. The surface markings of the parotid duct are marked on the skin of the face at the start of the operation and can be readily transposed to the surface of the parotid fascia once the flap has been raised. A line is drawn from the lowest point of the alar cartilage to the angle of the mouth. This line is bisected and the midpoint is joined by a straight line to the most posterior point of the tragus. The line is then divided into three equal parts. The middle section corresponds to the position of the parotid duct (Figure 46.1).

Incision

The incision starts in the hairline running downwards and backwards to the junction of the pinna and the temple. The incision then follows the pre-auricular attachment of the pinna skimming across the free edge of the tragus, following the attachment of the lobe posteriorly and then swinging gently down into a neck crease. Alternatively, the incision behind the attachment of the earlobe may be extended posteriorly into the hairline as with a face-lift incision. This variation results in a less visible scar, but surgical access to the parotid region is slightly more difficult. The incision is made either with a No. 15 blade or preferably with a very fine diathermy needle or ceramic blade. The incision is made through the skin just into the underlying fat.

Exposure of the parotid

The flap is raised either using a scalpel or by blunt dissection with scissors over the surface of the investing

Figure 46.1 Surface markings for the parotid duct.

layer of the deep cervical fascia which in this region splits to encapsulate the parotid (Figure 46.2). In this situation, the dissection can be deep to the superficial musculo-aponeurotic system (SMAS) as this layer will be returned to its anatomical position at the end of the operation. At the superior and anterior margins of the parotid gland, great care must be taken not to damage branches of the facial nerve which in these areas become very superficial. The flap must be raised just beyond the anterior border of the parotid. The flap is held forwards by suturing the flap to the head drapes with mattress sutures.

Identification of the parotid duct

The duct is identified where it emerges from the anterior border of the parotid. The surface marking of the duct is transferred on to the fascia. The fascia is incised along the line of the duct and, by careful blunt dissection, a search is made for the duct which is pinkish grey and covered with a fine capillary network. The branch of the facial nerve supplying the upper lip runs parallel with the duct either on its surface or a few millimetres superior to the duct. If the duct is not readily identifiable, it is useful to pass a fine IV cannula through the parotid papilla into the duct. This splints the duct and it can be easily palpated within the parotid (Figure 46.3).

Retrieving the stone

Once the duct has been identified at the anterior border of the parotid gland, it is fairly simple and rapid to follow it back into the substance of the gland. With fine scissors, the tissues overlying the duct are progressively separated and divided. Stay sutures through the edges of the dissection are used to retract the parotid. Provided the dissection continues in the plane immediately above the duct and the branch of the facial nerve to the upper lip is kept in sight, there is no risk to other branches which at this point have fanned out. Several fine intercommunicating branches will be encountered crossing the surface of the duct. Tributaries of the posterior facial vein are carefully clamped, divided and tied.

Once the calculus has been reached, it can be palpated through the duct wall. A longitudinal incision is made in the duct wall and the calculus is carefully teased out of the duct (Figure 46.4). The duct is then carefully irrigated proximally and distally with sterile saline or water to flush out any associated 'gravel' which if retained acts as a focus for recurrent stone formation (Figure 46.5).

Closure

No attempt should be made to suture the duct wall as this results in stenosis. The stay sutures are removed and the

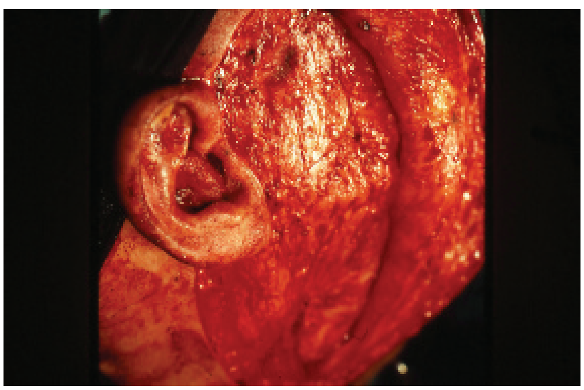


Figure 46.2 Exposure of the parotid fascia.

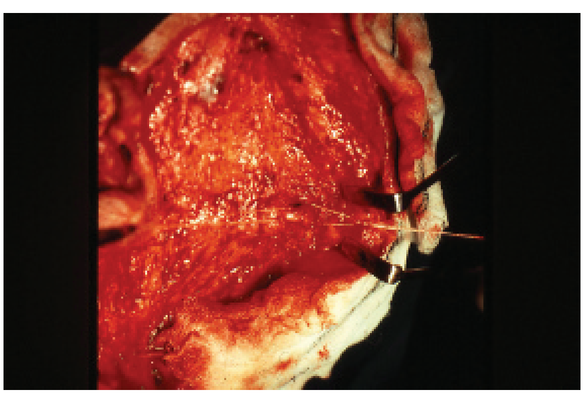


Figure 46.3 Identification of the parotid duct.

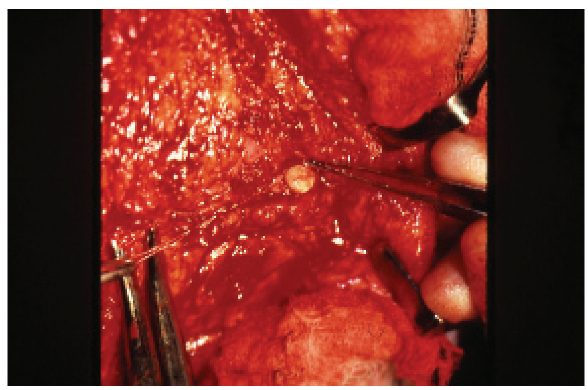


Figure 46.4 Exposure of the parotid stone.

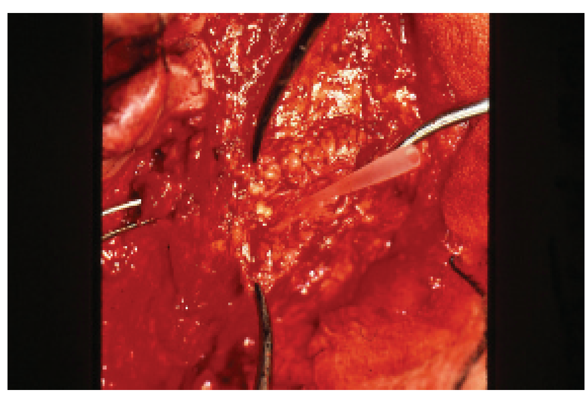


Figure 46.5 Flushing out the parotid duct.

parotid capsule closed with resorbable sutures. A small vacuum drain is inserted under the skin flap to avoid haematoma formation and the flap is closed in two layers.

Post-operative care

As the parotid gland is likely to be infected proximal to the site of the calculus, antibiotics are administered for 3 days post-operatively. The drain is removed at about 24 hours and the skin sutures are removed after 5 days.

Complications

Apart from anaesthesia in the territory of the skin flap, there are few complications. As the fascia forming the capsule of the parotid gland is closed, salivary fistula and Frey's syndrome do not occur. The paraesthesia gradually resolves as the cutaneous sensory fibres regenerate from the periphery. If a face-lift incision has been utilized, healing is normally excellent and after 6 months the scar becomes almost invisible. However, if a conventional lazy-S incision has been used, hypertrophic scarring sometimes occurs in the cervical extension of the incision. For this reason, patients should be followed up carefully for the first 6 months so that, if hypertrophic changes are seen, the scar can be treated appropriately. Weekly infiltration with triamcinalone acetonide will usually prevent further scarring.

SUPERFICIAL PAROTIDECTOMY

Indications

Treatment of parotid tumours is classically by superficial lobectomy for all tumours within the superficial lobe and total parotidectomy for all tumours within the deep lobe. Such deep lobe tumours should never be approached from the pharyngeal aspect even when they present as lateral pharyngeal masses. The facial nerve, if not macroscopically invaded by malignant tumour, is preserved in all cases. For small tumours arising in the superficial lobe, careful extracapsular dissection may be undertaken (see Chapter 45).

Surgical anatomy

The key to successful parotid surgery is the observation of the two following anatomical features (Figure 46.6):

1. The parotid gland has two lobes (superficial and deep) united by an isthmus. The parotid gland is not embryologically a bilobed structure, but its developmental relationship to the facial nerve results in the two surgical lobes
2. The facial nerve and its branches are surrounded by these lobes, invested in loose connective tissue. The facial nerve, except when invaded by tumour, does not enter the substance of the gland.

The following are four anatomical landmarks leading to the identification of the trunk of the facial nerve as it leaves the stylomastoid foramen (Figure 46.7):

1. The cartilaginous external auditory meatus forms a 'pointer' its anterior inferior border indicating the direction of the nerve trunk.
2. Just deep to the cartilaginous pointer is a reliable bony landmark formed by the curve of the bony external meatus and its abutment with the mastoid process. This forms a palpable groove leading directly to the stylomastoid foramen. Unfortunately, this groove is filled with fibrofatty lobules that often mimic the trunk of the facial nerve, which can lie as much as 1 cm deep to this landmark.

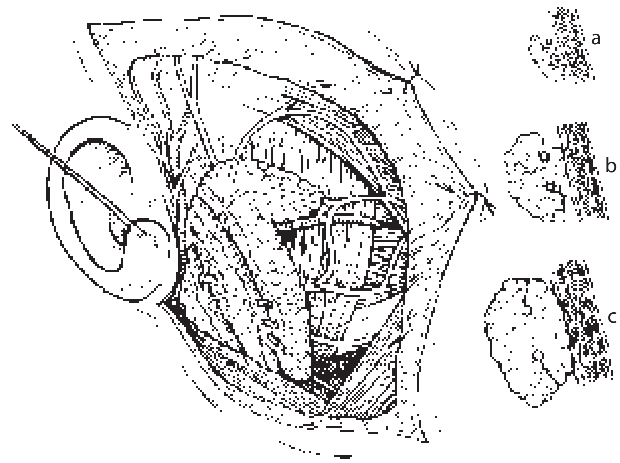


Figure 46.6 Development of the parotid gland to engulf the branches of the facial nerve.

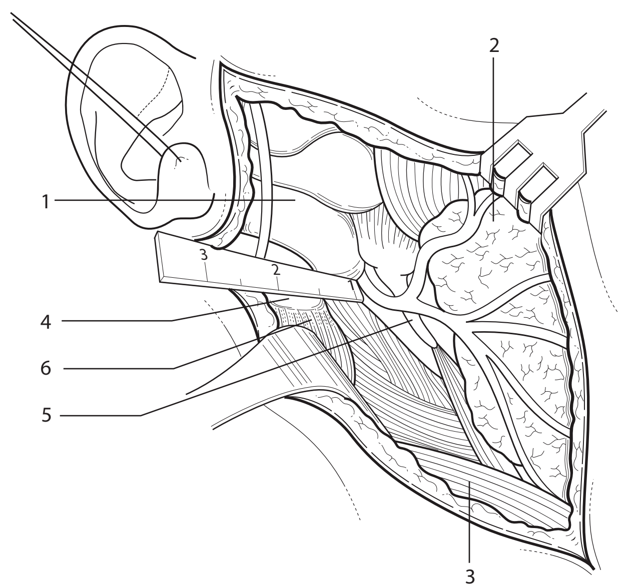


Figure 46.7 Anatomical landmarks leading to the identification of the facial nerve trunk. 1 cartilagenous external meatus; 2 parotid gland; 3 sternocleidomastoid muscle; 4 tip of the mastoid process; 5 styloid process; 6 posterior belly of digastric muscle.

3. The anterior superior aspect of the posterior belly of the digastric muscle is inserted just behind the stylomastoid foramen.
4. The styloid process itself can be palpated superficial to the stylomastoid foramen and just superior to it. The nerve is always lateral to this plane and passes obliquely across the styloid process. A branch of the post-auricular artery is usually encountered just lateral to the nerve.

Anaesthesia

The operation is performed under general anaesthesia. The patient is placed supine with a sand bag or pad under the shoulder on the side of the operation. The neck is moderately extended and the head is turned to the opposite side. The table is tilted 'tilted' to reduce venous engorgement. The anaesthetist should be requested to drop the blood pressure to reduce capillary and artereolar bleeding. The incision line is infiltrated with lignocaine hydrochloride and 1:80,000 epinephrine (adrenaline).

Incision

The incision starts in the temporal region and passes inferiorly in the pre-auricular crease, crossing the base of the tragus and passing posteriorly behind the lobe of the ear. It then either extends posteriorly into the hairline as in a face lift or alternatively swings down inferiorly from the mastoid to continue in a neck crease. The incision may be made either with a No. 15 blade or with fine needle diathermy or a ceramic blade. The skin flap may be raised in the plane of the pre-parotid fascia, but if it is raised superficial to the SMAS, this layer can be mobilized as a separate exercise and used to cover the raw surface of the parotid avoiding much of the cosmetic deformity and the incidence of Frey's syndrome. The flap is held forward by suturing the margins of the flap to the adjacent head drapes (Figure 46.8).

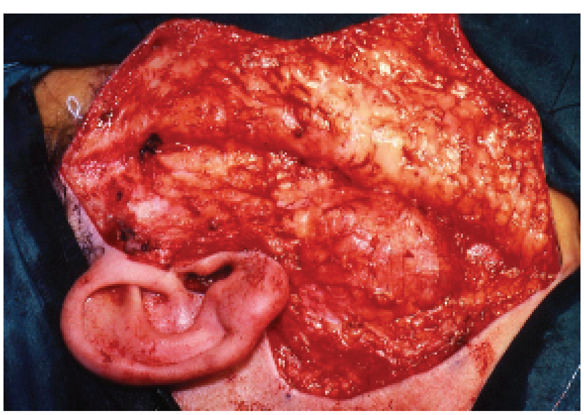


Figure 46.8 Flap elevated to expose the superficial lobe of the parotid gland.

Identifying the trunk of the facial nerve

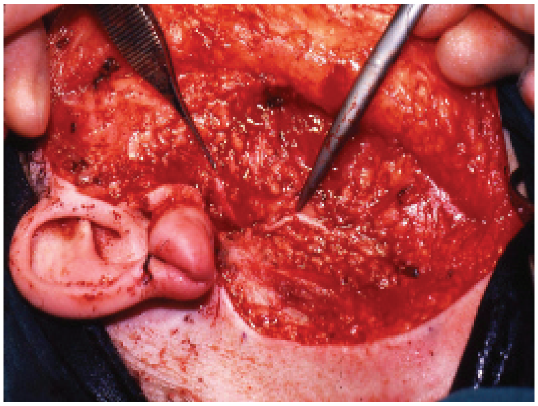
The routine use of a nerve stimulator as a guide to the position of the facial nerve is not advocated as it may be misleading due to tissue conduction or fatigue of the nerve. The blood-free plane anterior to the cartilaginous meatus is opened up by blunt dissection with scissors. This leads down to the base of the skull just superficial to the styloid process and the stylomastoid foramen and defines the depth of the dissection. This plane is then gently opened up in an inferior direction by blunt dissection until the trunk of the facial nerve is seen. It is usually possible to preserve the posterior branch of the great auricular nerve if care is taken to avoid dissecting too deep to the earlobe.

With large posterior tumours, this plane may be difficult to open up. In this situation, it is helpful to identify the posterior belly of the digastric muscle in the cervical extension of the incision. The anterior border of the sternocleidomastoid muscle is mobilized and retracted inferiorly to display the digastric muscle beneath it. This manoeuvre necessitates sectioning the great auricular nerve. The posterior belly of the digastric muscle is traced upwards and backwards to its insertion on to the mastoid process which lies immediately below the stylomastoid foramen, thus leading the operator to the facial nerve from below (Figure 46.9a and b).

Very rarely, most often after recurrent infection with fibrosis or previous radiotherapy, the trunk of the facial nerve cannot be confidently identified. In this situation, the peripheral branches of the nerve at the anterior border of the parotid are identified and traced centrally towards the stylomastoid foramen.

Removal of the superficial lobe

Once the facial nerve trunk has been identified, the superficial lobe of the parotid can be 'exteriorized' by opening up the plane in which the branches of the facial nerve run between the two lobes using blunt dissection. Initially, as it leaves the stylomastoid foramen, the trunk of the facial nerve turns abruptly to become more superficial and also divides into the larger zygomaticofacial trunk and smaller cervicofacial trunk. The five main branches of the nerve are then followed centrifugally through the parotid until the superficial lobe is completely freed. This part of the operation is performed using fine scissors, opened up in the plane of the facial nerve branches, with care always taken to identify the nerve fibre before dividing parotid tissue (Figure 46.10a and b). During the lower part of the dissection, branches of the posterior facial vein will be encountered immediately deep to the marginal mandibular branch of the facial nerve. Great care must be taken when vascular clamps are applied to these branches to avoid damaging the facial nerve. If the superficial parotidectomy is being performed for chronic infection, the duct should be tied off as far forward as possible to prevent recurrent ascending infection.



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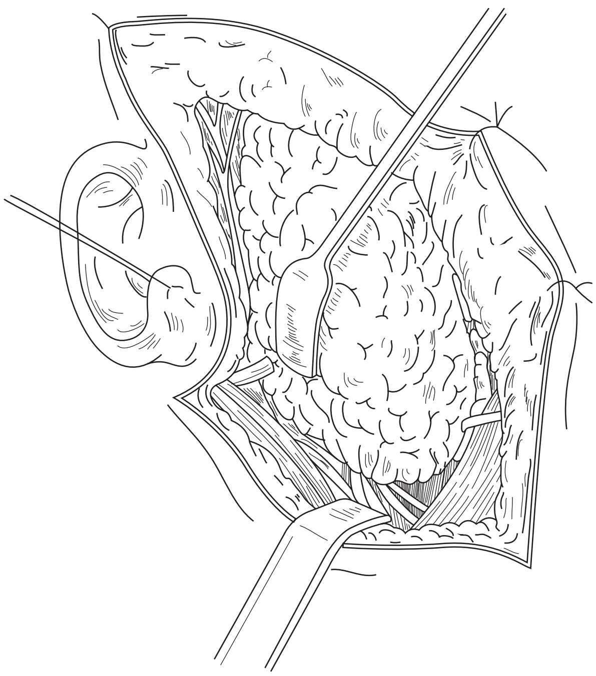
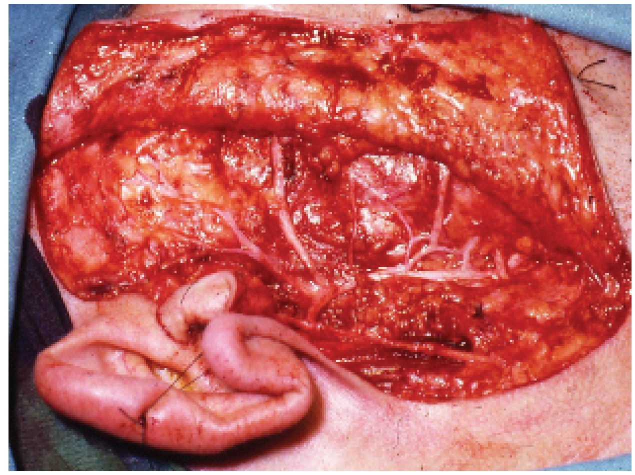


(b)

Figure 46.9 (a) Identification of the facial nerve trunk. (b) Identification of the facial nerve trunk at the insertion of the posterior belly of the digastric muscle into the mastoid process.



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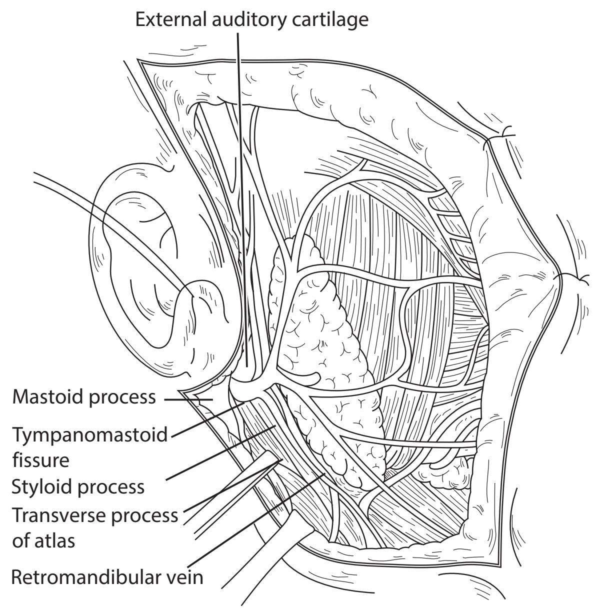


(b)

Figure 46.10 (a) Completed dissection of the facial nerve following superficial parotidectomy. (b) Anatomical landmarks following superficial parotidectomy.

Partial superficial parotidectomy

When the tumour lies within the tail of the parotid gland, there is no necessity to dissect all the branches of the facial nerve nor to remove the entire superficial lobe. Once the main division of the nerve trunk has been identified, only the cervicofacial trunk needs to be followed and the inferior part of the superficial lobe is mobilized and ultimately removed.

Similarly, if the tumour lies above the level of the meatus, only the zygomaticofacial trunk should be dissected and the corresponding part of the superficial lobe is removed.

Total parotidectomy

If the tumour lies in the deep lobe of the gland, a conventional superficial parotidectomy is performed as described. Next, the branches of the facial nerve are mobilized and lifted on nylon tapes to enable the deep lobe to be freed around its margins and removed by dropping it downwards (Figure 46.11). As this space is wedge-shaped with its apex superior, it is almost invariably possible to do this. The deep lobe is covered by a capsule (the deep layer of the deep cervical fascia which splits to envelope the parotid) and is surrounded by the parapharyngeal fat. Thus, it is relatively easy to mobilize the deep lobe by blunt dissection either with scissors or with a finger (Figure 46.12). Only very rarely it is necessary to perform

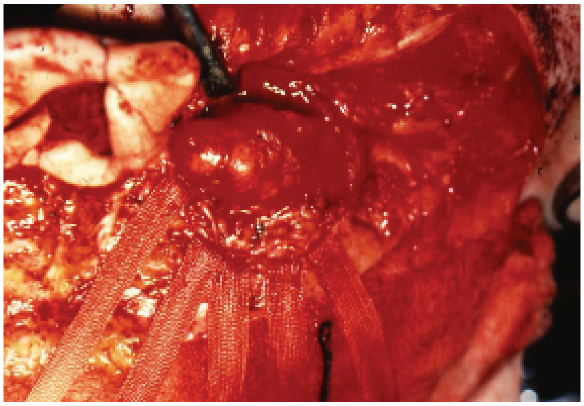


Figure 46.11 Mobilization of the branches of the facial nerve to gain access to the deep lobe.

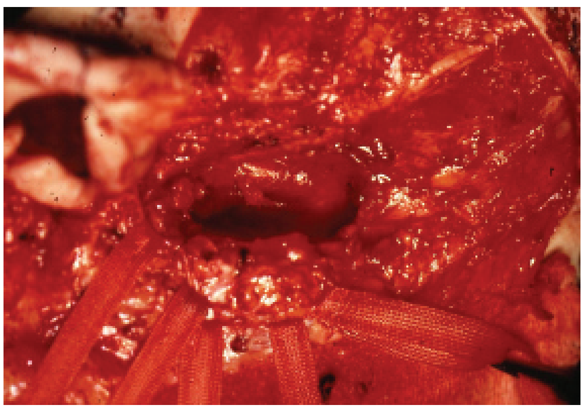


Figure 46.12 Mobilization of the deep lobe of the parotid gland.

a mandibulotomy (either vertical subsigmoid or angle) to gain access to the deep lobe.

Closure

Following the removal of the parotid, the blood pressure is returned to normal and the head-up tilt returned to horizontal. All bleeding points must be meticulously controlled. A vacuum drain is inserted under the flap and the wound carefully closed in two layers (Figure 46.13). A firm pressure dressing will help to prevent any collection of blood or saliva under the flap.

Post-operative care

The pressure dressing, if used, is removed at about 12 hours and the vacuum drain at 24 hours if the wound is no longer draining. Skin sutures are removed after 5 days.

Complications

Permanent facial nerve paralysis following superficial or total parotidectomy is very rare, except when branches of the facial nerve have been deliberately sacrificed. When the

Figure 46.13 Two-layer closure with a single vacuum drain prior to the application of a pressure dressing.

facial nerve or its branches are sacrificed as a result of macroscopic tumour involvement, an immediate nerve graft may be undertaken using conventional microneural techniques. Temporary weakness due to neuropraxia occurs in approximately 20% of operations, but recovers usually within 6 weeks.

Anaesthesia of the skin flap slowly resolves as the sensory nerves regenerate from the periphery over a 4-month period. Anaesthesia of the earlobe due to sectioning of the great auricular nerve can be troublesome particularly when the subject has pierced ears. Recovery can take up to 18 months and may not be complete. Furthermore, a painful amputation neuroma can develop on the stump of the sectioned nerve and requires excision.

Frey's syndrome (gustatory sweating) is a regular sequel to parotidectomy occurring in more than half the patients if looked for carefully. The only effective way to control the symptoms if troublesome is to map out the area of sweating and then infiltrate the subcutaneous plane with botulinum toxin. This will need to be repeated at intervals of 4–6 months.

Other rare complications, such as sialocoele or salivary fistula, occasionally follow parotidectomy. Both complications are managed conservatively and resolve spontaneously after days or weeks. Very rarely, a parotid fistula persists despite attempts at surgical closure. In this situation, post-operative radiotherapy will destroy any residual functioning glandular tissue and allow the fistula to close.

Parotidectomy can result in a significant cosmetic defect with hollowing of the facial contour behind the mandible. Where this is likely to be a problem, the superficial part of the sternocleidomastoid muscle can be mobilized, transacted inferiorly and swung up to cover the defect (Figure 46.14). The flap must be anchored in place with non-absorbable sutures as it tends to pull down into the neck.

The superficial SMAS flap

The superficial SMAS can be elevated as a separate flap if the skin flap is raised in the subcutaneous layer

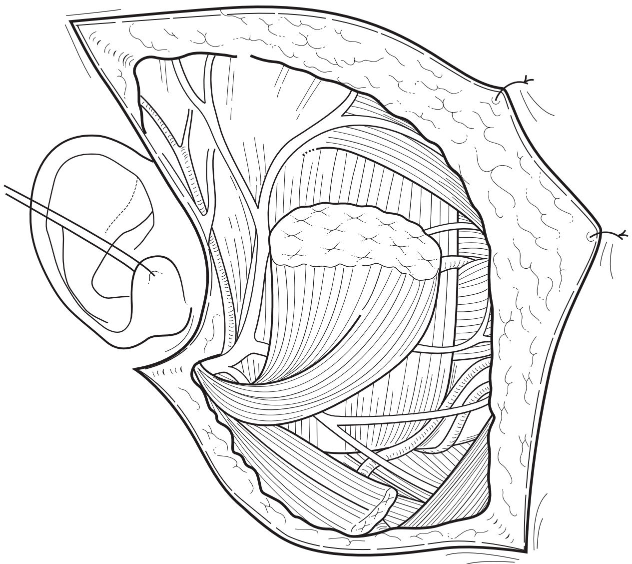


Figure 46.14 Sternocleidomastoid muscle flap turned up to restore the cosmetic defect following parotidectomy.

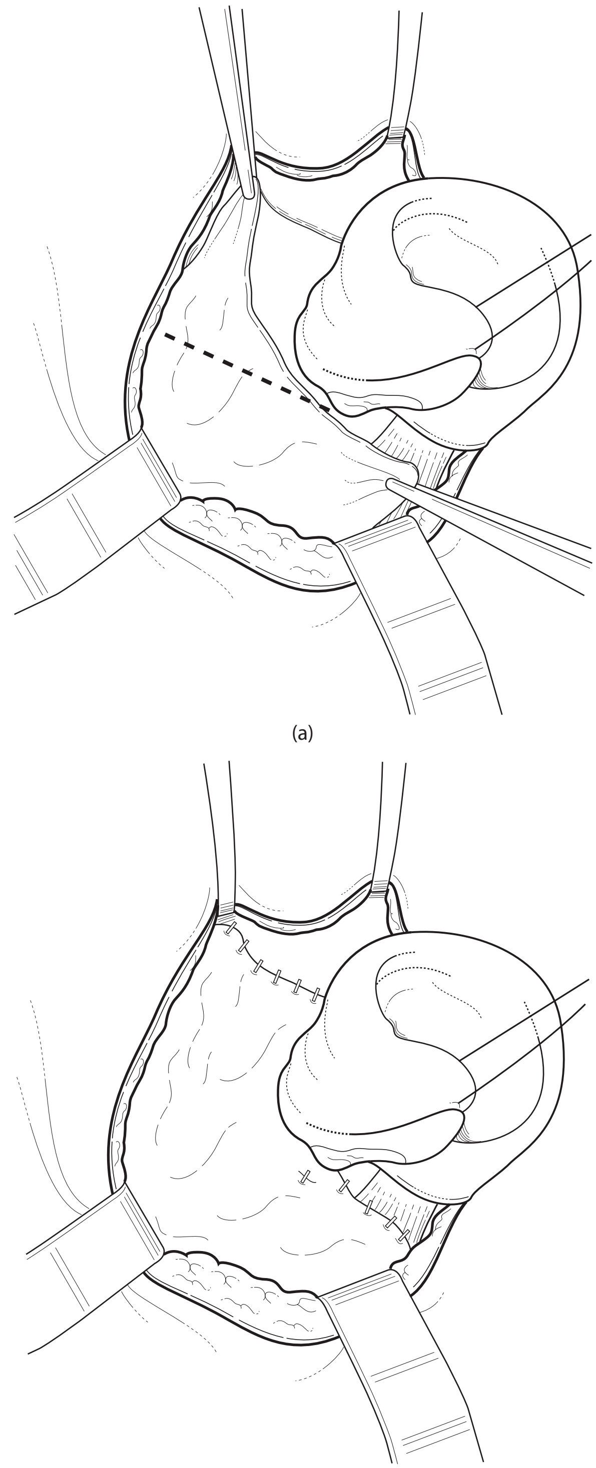
(Figure 46.15a). On completion of the parotidectomy, the SMAS layer can be mobilized to cover the defect behind the mandible by suturing its free edge posteriorly to the anterior border of the sternocleidomastoid muscle and periosteum of the zygomatic buttress (Figure 46.15b). This will also partially advance the skin flap and excess tissue may need to be trimmed. Great care must be taken when a tumour lies very superficially within the parotid. Mobilizing the SMAS flap can very easily rupture the tumour capsule and it is better to buttonhole the flap overlying the tumour rather than risk rupture. The evidence suggests that not only does the use of the SMAS flap improve the cosmetic result, but it also dramatically reduces the incidence of Frey's syndrome.

Tumour spillage

Spillage of a benign pleomorphic adenoma should not occur if a formal parotidectomy is undertaken. However, the following are four circumstances where even with meticulous surgical technique this can happen:

1. Extremely large pleomorphic adenomas occupying the entire superficial lobe making mobilization of the gland difficult. In this circumstance, it may be better to dissect the facial nerve from the periphery.
2. Tumours that are intimately associated with branches of the facial nerve requiring very delicate dissection along the capsule of the tumour to release the nerve.
3. Tumours with lobular extensions extending beneath the mastoid, zygomatic arch or mandible.
4. Some tumours that are abnormally friable with even routine retraction of the superficial lobe resulting in rupture.

If rupture does occur, an extremely careful inspection of the wound must be undertaken and the area thoroughly irrigated. The circumstances should be discussed subsequently at the head and neck cancer multidisciplinary team (MDT) meeting for consideration of prophylactic post-operative radiotherapy to prevent multiple recurrences due to tumour seeding.



(a)

(b)

Figure 46.15 (a) Area of undermined superficial musculo-aponeurotic system (SMAS) flap. The 'hinge' is indicated by the dotted line. (b) Re-attachment of the SMAS flap to the zygomatic buttress and sternocleidomastoid muscle.

ADVANCED MALIGNANT TUMOURS

In a small proportion of cases, the subsequent histopathological diagnosis will be of malignancy. Provided the tumour was intrinsic to the parotid and the tumour was not ruptured during parotidectomy, no other surgery is necessary or desirable. Each case should be discussed at the MDT meeting and considered for post-operative radiotherapy. In general, all high-grade tumours should be treated with radiotherapy and also those where there is any doubt about the margins being clear.

Patients with advanced disease with extension beyond the parotid capsule into adjacent tissues or with lymphatic metastasis should be treated by a sound oncologic technique according to the specific circumstances (Figure 46.16a and b). Often this will include mandibular resection, clearance of the infratemporal fossa and neck dissection and on occasion resection of the temporal bone (Figure 46.17a and b). If any of the branches of the facial nerve are functioning pre-operatively, they may be preserved as evidence suggests that radical sacrifice of the facial nerve does not improve survival.

EXTENSIVE DEEP LOBE AND OTHER PARAPHARYNGEAL TUMOURS

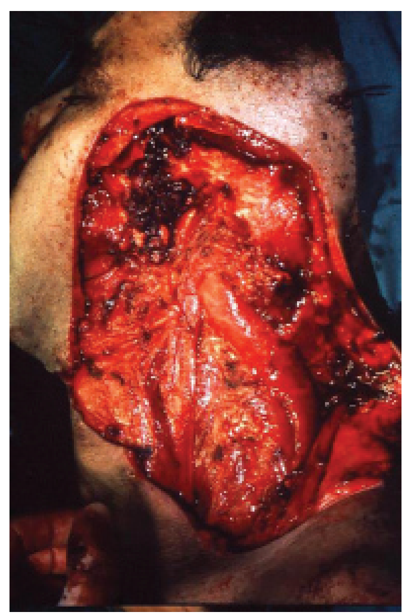
On occasion, very extensive deep lobe parotid tumours develop with minimal signs and symptoms. In such circumstances, a transpharyngeal approach using a lower lip split and mandibulotomy with mandibular swing will give adequate access to the deep lobe and infratemporal fossa.

(a)

(b)

Figure 46.16 (a) Malignant parotid tumour with cervical metastasis. (b) Total parotidectomy and neck dissection with preservation of the facial nerve.

(a)



(b)

Figure 46.17 (a) Recurrent high-grade mucoepidermoid carcinoma causing intractable pain. (b) Radical tumour resection including the mandibular ramus and temporal bone.

TRANSPHARYNGEAL APPROACH TO THE DEEP LOBE

Although this approach is mostly used for large extraparotid masses, it is occasionally indicated for the exceptional tumour arising in the deep lobe (Figure 46.18). After anaesthetic induction, an elective tracheostomy is performed as there can be considerable swelling in the oropharynx post-operatively.

Incision

A skin crease incision is made from the level of the hyoid bone and extended forward towards the chin point. At this point, the incision is continued either around the chin point or vertically in the midline. The decision is dictated according to the local anatomy. In patients with a pronounced chin cleft, it is best to use a midline vertical incision and for those with a well-developed chin button dictate it is preferable to incise around this (Figure 46.19). The lower lip is split in the midline, but a notch should be incorporated in the incision line at the vermillion border. These help with the aligning of the vermillion border at skin closure and also acts as a Z-plasty to prevent tethering of the lower lip.

Exposure

After retraction of the sternocleidomastoid muscle posteriorly, the carotid sheath is isolated and traced upwards to the skull base. Vascular slings are placed around the internal and external carotid arteries in case either vessel is ruptured later in the operation and urgent control is required. Often it is sensible to clamp, divide and ligate the external carotid at this stage.

The dissection is then continued forward deep to the submandibular salivary gland. It must be carefully freed from the underlying hyoglossus and mylohyoid muscles, whilst remaining attached to the lower border of the mandible.

The surgeon should then return to the chin incision and expose the buccal aspect of the mandible from the midline back to the premolar region carefully isolating the mental nerve as it exits the foramen between the premolar roots.

The mandibulotomy is then marked running between the first premolar and canine teeth (Figure 46.20). Two microplates are then adapted to the buccal aspect of the mandible and the screw holes drilled. The plates are then carefully put aside, care being taken to mark them for position and orientation.

The mandibulotomy cut is then made with a reciprocating saw. Great care must be taken between the two adjacent teeth so as not to damage the roots. It may be wise to cut just through the buccal cortex with a bur and continue the mandibulotomy with a very fine osteotome at

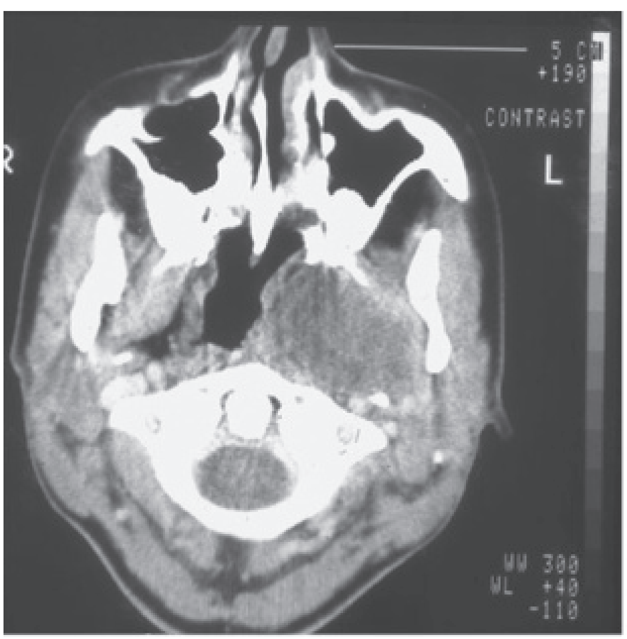


Figure 46.18 Computed tomography scan showing an extensive deep lobe tumour requiring a transpharyngeal approach.

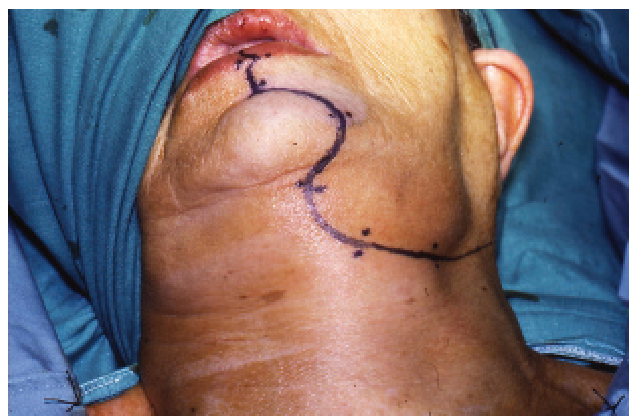


Figure 46.19 Lip split incision to expose the mandible.

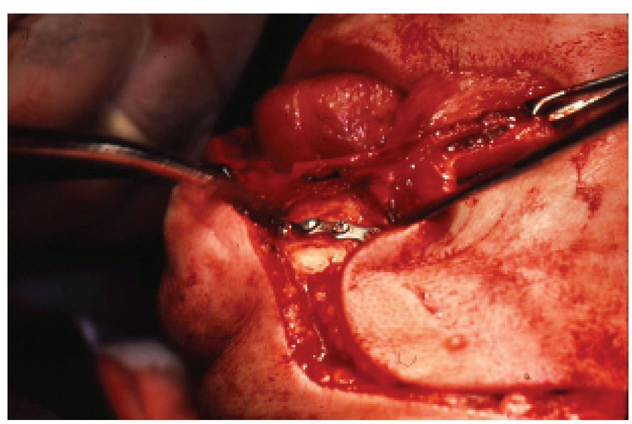


Figure 46.20 Exposure of the mandible and application of the first manipulate prior to mandibulotomy.

this level. The mandible is then retracted laterally and the mucosal incision extended posteriorly along the floor of the mouth medial to the submandibular duct. The incision should extend up the anterior pillar of the fauces to the upper pole of the tonsil.

During this stage of the operation, the lingual nerve and the hypoglossal nerve must be identified. The hypoglossal nerve can be readily displaced medially and protected, but it may be difficult to release the lingual nerve sufficiently. In this case, the nerve should be cleanly divided with a blade and the ends tagged, so that an anastamosis can be performed at the end of the operation.

At this stage of the operation, the parapharyngeal space can be opened through the incision and the tumour mobilized and delivered by blunt dissection.

Closure

Following meticulous haemostasis, a vacuum drain is inserted into the parapharyngeal space. The intra-oral incision is closed in at least two layers with the mucosa being closed with everting mattress sutures as it is important to achieve a watertight closure to prevent the formation of an orocutaneous fistula. At this stage, the lingual nerve should be repaired with micro neural techniques if it has been previously divided. Once the floor of the mouth has been repaired, the previously adapted microplates are screwed into their previously drilled holes and mandibular continuity is restored without any disturbance to the occlusion.

The skin incision is closed in two layers. Great care must be taken with the lip closure. The orbicularis muscle should be repaired with resorbable sutures before commencing a two-layered closure of the skin. It is very important to achieve perfect alignment of the vermillion as failure to achieve this result in a very unsightly scar. The drain is removed usually at 24 hours and the skin sutures at 7 days.

Complications

The greatest risk with this operation is the development of an orocutaneous fistula. Watertight closure of the mucosal incision is vital. Should a fistula develop, it is worth returning the patient to the operating theatre and resuturing the mucosa where it is leaking. If this is done, the drainage through the neck will close spontaneously.

Damage to the teeth adjacent to the mandibulotomy can be prevented by careful technique at the time of the operation. The lingual nerve repair will normally give useful function, but sensation almost never returns completely. The patient should have been warned of this pre-operatively.

Top tips

- Surgical biopsy of an intrinsic parotid tumour carries a severe risk of seeding tumour cells into the adjacent tissues and rarely affects the definitive surgical procedure.
- Although embryologically composed of a single lobe, the parotid gland consists of two surgical lobes separated by the facial nerve which is enclosed in loose connective tissue.
- The trunk of the facial nerve is very constant anatomically. It should be identified before any facial nerve dissection, except when a centripetal approach is to be used. The anatomical landmarks are 100% reliable.
- The great majority of deep lobe tumours may be safely removed without dividing the mandible.
- Preserving the SMAS and re-attaching it at the end of a parotidectomy improve the cosmesis and dramatically reduce the incidence of Frey's syndrome.
- The only reliable way of controlling Frey's syndrome is the subcutaneous infiltration of botulinum toxin into the affected area.

SUGGESTED READINGS

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Extracapsular dissection

MARK MCGURK, LUKE CASCARINI and RABINDRA P SINGH

CONTENTS

PRINCIPLES OF JUSTIFICATION

Extracapsular dissection (ECD) is an example of the general move towards minimally invasive procedures. Historically, pleomorphic adenomas in the parotid gland have had a reputation for tumour recurrence. Consequently, an approach was adopted towards superficial or total conservative parotidectomy.

The reputation for pleomorphic adenomas having a propensity to recurrence is largely undeserved. The reason for this is that in the 1930s, when the high incidence of recurrence was noticed, these lesions were thought to be hamartomas and not true neoplasms. They were called *pathological adenomas*. Consequently, it was an acceptable practice to enucleate these lesions after opening the capsule, in essence an intra-capsular dissection. It was soon realized that a significant number recurred. In response, a number of surgeons started to develop new techniques to deal with these parotid lumps and with the seminal work of Patey and Thakray in 1958, the techniques of superficial parotidectomy (SP) and total conservative parotidectomy became the universal standards of care for the wrong reason, but correct result. The incidence of recurrence dropped with this change, thus reinforcing the intellectual and scientific bases underpinning these techniques.

However, in the late 1940s, before the debate had been resolved in favour of superficial and total parotidectomies, general surgeon Alan Nicholson at the Christie Hospital, Manchester, UK was continuing with his own local dissection technique. By the late 1950s, when the debate was settled in favour of SP, Nicholson had 10 years of experience with the ECD technique without evidence of recurrence. Consequently, he continued with this technique and was followed in turn by other surgeons both at Guy's Hospital, London, UK and Erlangen, Germany where over 1200 cases of benign parotid tumours have been treated by ECD. In reality, surgeons have been dissecting benign tumours in an extracapsular plane ever since the conservative parotidectomy technique was conceived because the tumour surface is in direct contact with one or more branches of the facial nerve in 60% of the cases. Two recent systematic reviews and meta-analysis have supported the role of ECD in benign parotid tumour management with significantly reduced risk of temporary facial nerve weakness and Frey's syndrome in ECD compared to SP. Albergotti et al.,[1] in an analysis of 1882 patients, found similar rate of tumour recurrence (1.5% ECD vs. 2.4% SP) and permanent facial nerve paresis with ECD and SP. On the other hand, Foresta et al.[2] analyzed a total of 2562 patients and suggested significantly reduced risk of tumour recurrence and permanent nerve weakness with ECD. The evidence is now beginning to favour ECD as a viable and safe technique in the management of benign parotid tumours against the long-held views supporting more extensive traditional surgical techniques.

Indications

ECD is only appropriate for benign tumours of the parotid gland. It has no application in submandibular gland because the morbidity of ECD and submandibular gland removal are the same. There is no facial nerve to complicate the equation. But the basic principle of a conservative extracapsular resection is applicable to pleomorphic adenomas of the junction of hard and soft palate. Resection of bone on the hard palate or soft-tissue

aponeurosis to form a nasal fistula is completely unjustified (see Chapter 44).

Every effort should be taken to avoid inadvertent ECD of a salivary malignancy. This error of patient selection, which has probably delayed general acceptance of the technique of ECD, happens rarely and only occurs with very low-grade lesions masquerading as benign lumps. Clinically, it is difficult to discern these tumours when they are small, as they have not had time to declare themselves. Consequently, it is the small apparently benign parotid lumps that present a challenge, not the 2 or 3-cm diameter lesions. Also, small lumps are easily missed on fine-needle aspiration so that normal benign tissue is sampled inadvertently. Therefore, small parotid tumours should be approached with caution and if ECD is being considered, the cytological evidence should be checked carefully. Also, it is a very simple matter with these small 8–15-mm lesions to continue to ECD with a margin around the lesion of 1 cm if required. A conventional parotidectomy is also an option but is not normally required from an oncological perspective as most patients with malignant parotid lumps get adjuvant radiotherapy because of the proximity of the facial nerve and the inability to achieve a 5-mm margin.

The ideal lesion is a well-defined lump, 2–6 cm in diameter, in the superficial portion of the parotid gland, the circumference of which can be defined by palpation. With time and experience, most parotid lumps irrespective of their position are amenable to the ECD technique.

Pre-operative

Although there is evidence that some clinicians can discern benign from malignant tumours in over 90% of cases by clinical examination alone, it is prudent to undertake fine-needle aspiration cytology assessment as it is a simple technique that can improve the diagnostic rate even further.

The role of imaging in benign superficial parotid tumours is debatable, but reconnaissance is never wasted. Imaging is open to individual preference. With increasing experience, the surgeon will tend to reduce the use of imaging. It has increasing application as the tumour is less easy to inspect digitally.

Anaesthesia

Hypotensive anaesthesia is not necessary for ECD. Haemostasis is a surgical responsibility, not an anaesthetic one. If a paralyzing agent is used, it should be short acting as it is important that the patient is not paralyzed during the surgery. Continuous nerve monitoring does no harm and may rescue the tired or distracted surgeon from a misadventure.

The patient's neck is extended as it makes the parotid gland more prominent, this can be done by placing a small pack beneath the nape of neck. A nasal endotracheal tube is used as an oral tube, by opening the mouth, makes it difficult to draw the mandible forward which is necessary when the tumour is wedged between the ramus of the mandible and the mastoid process. The patient is supine with the operating surgeon on the same side as the tumour with the head turned away. The drapes are placed to leave the ipsilateral face exposed for facial twitching is the ultimate indicator of proximity to the facial nerve.

It is important that the surgeon is comfortable, usually sitting with adequate support of the arms. Most surgeons use some degree of magnification for this procedure, such as surgical loupes.

Incision

A bloodless field is achieved by infiltrating the pre-auricular tissues with 20–30 mL of 1:200,000 epinephrine solution. This provides a dry surgical field and hydro-dissects the subcuticular tissues from the parotid fascia. The solution is injected early in the procedure so it has time to induce adequate vasoconstriction.

The proposed incision should be marked; it is useful to put superficial scratch marks or skin staples on either side across this incision line in order to relocate the skin flap. This is particularly so around the lobe of the ear, which has an annoying habit of becoming distorted after surgery. The standard approach for ECD is a pre-auricular incision with cervical extension along a natural skin crease. But with experience the length of incision can be reduced and tailored to the individual lump. When commencing ECD, the advice is to use the same extent of exposure as traditional SP.

Shaving the patient's hair has no impact on healing; it can be swept back and tied or taped away so it is kept out of the surgical field.

Dissection

The skin is raised in a plane immediately superficial to the parotid fascia. This is a shining white plane, which is easy to identify and follow forward until the fibres of the platysma muscle are encountered. The lobe of the ear should be freed from the mastoid process and both the skin flap and the ear are retracted with sutures. At this point, the great auricular nerve should be identified as it runs over the sternomastoid muscle and in approximately 60% of cases of ECD it can be preserved.

When the skin flap has been raised, the clinical features of the tumour are checked once again. If the lump is clearly mobile and there are no features of tethering to suggest malignancy, then ECD can proceed. A new approach that has transformed the approach to the parotid lump, especially those towards the posterior aspect of the parotid and wedged between the mandible and mastoid is to approach the procedure like an upper neck dissection. The posterior skin flap is developed to expose the sternomastoid muscle (with the deep cervical fascia intact). Then, longitudinal incision is made along the anterior border of the muscle (1 cm from its edge). The fascia is carefully lifted off the

muscle and followed down its deep surface to the accessory nerve. The parotid is released and can be rotated anteriorly. What was wedged between the ramus and mastoid is freely visible and easy to access. In all cases, apart from a very superficial tumour on the lateral surface of the parotid, this rotation approach should be used. It is perfect for the Warthin's tumour in the distal aspect of the tail of the gland.

Once exposed, the periphery of the tumour is marked in ink and a cruciform incision drawn across the surface (Figure 47.1). It is very important that this incision extends for at least 1 cm beyond the tumour margin as it improves access to the tumour. Four artery clips are attached to the centre point (Figure 47.2) and used to provide upward tension whilst the parotid fascia is incised along the cruciform lines.

The key to ECD is finding a safe plane in which to dissect. This is done by drawing the normal parotid tissue away from the tumour revealing tissue planes 2 or 3 mm wide of the tumour capsule. The rule is that no instrument should be used to retract the tumour. If it no longer has a cushion of protective normal tissue, it can only be retracted by finger pressure, but retractors can be used to hold back the normal parotid tissue. The artery clips are left attached to the parotid fascia and continually used as retractors. It cannot be emphasized more strongly that the retraction must be on the normal parotid tissues adjacent to the tumour and never on the tumour itself.

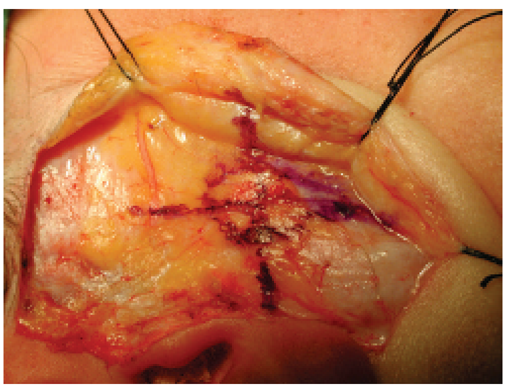

Figure 47.1 Skin flap raised and cruciform incision marked.

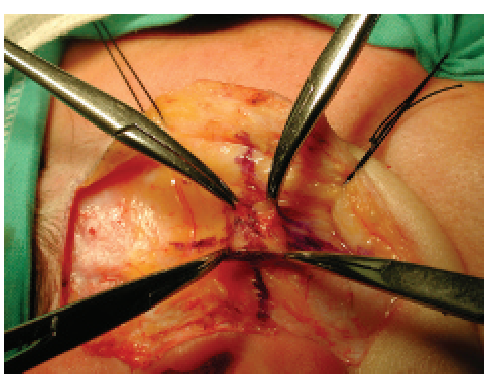

Figure 47.2 Parotid fascia raised with traction from artery clips.

The process of dissection in the safe plane is identical to that used in SP when exposing the trunk of the facial nerve. The closed end of a pair of blunt-tipped scissors or artery clip is pushed gently through thin sections of parotid tissue and opened with upward pressure to part the parotid tissue. It is imperative that no tissue is cut without seeing the scissors through the fascia. In this way, a facial nerve branch is readily identifiable. If a branch of the facial nerve enters the surgical field, it is traced forward for a short distance (5–10 mm) to reveal its position and if in close contact with the capsule is dissected from the tumour. If the tumour arises from below the facial nerve in the deep lobe of the parotid gland, then all that is required is that the branches of the facial nerve are dissected off the tumour capsule or periphery and the ECD continues as normal with dissection around the periphery of the lesion until it is free. This situation is no different from that encountered in SP.

Another important point is to work slowly around the periphery of the tumour. If at any point the dissection becomes difficult, the surgeon should move to another area of the tumour. One should avoid working in the bottom of a hole. If this is the case, the cruciate incision should be extended to improve exposure. Extending the incision allows the parotid lump to be delivered up and improves access immediately.

It is not necessary to search for the facial nerve; an unseen nerve is a safe nerve. It is the dissection of the nerve and inadvertent trauma that produces facial nerve damage. Once the tumour is delivered, the parotid fascia is re-approximated along the lines of the cruciform incision and closed with multiple, interrupted, resorbable sutures. This restores the contour of the cheek, eliminates any dead space within the parotid gland and the closed fascia and also minimizes the risk of Frey's syndrome. The skin flaps are closed in two layers over a suction drain and a mastoid-type pressure dressing is applied.

Post-operative

The pressure dressing is left in situ for 24 hours. It is important that it is taken down the next day in order to check on the perfusion of the helix. It is mostly possible to discharge the patient home on the first post-operative day or on occasions, on the same day.

Complications

The risk of tumour rupture is the same as SP (1%–3%). If such an event occurs, the operation should be stopped. A clean sucker should be used to suction up any spilt tumour. The sucker should then be discarded. The tear in the tumour capsule should be closed with surgical tissue glue in the first instance. Liga clips or sutures tend to aggravate the situation by making the tear even bigger.

The operative field should be thoroughly washed with sterile water. The operation is then recommenced but the tumour is no longer handled at all. If this routine is followed and contamination is minimal, then the risk of recurrence is about 8% at 15 years. If gross contamination of the wound is encountered, then the risk of recurrence is increased and the possibility of adjuvant radiotherapy should be discussed at the multidisciplinary meeting and indeed with the patient.

Haematomas

The parotid gland is a vascular structure and the risk of post-operative haematoma is always present. There does not seem to be any greater or lesser risk with ECD. Meticulous haemostasis should be achieved throughout the procedure and also small bleeding points should be identified and carefully cauterized. A suction drain is an option and should be used if a lot of dissection has occurred in the parotid. The one essential item is a pressure dressing. This is a formal mastoid dressing; without it, the risk of sialocoele and haematoma is raised.

Facial nerve injury

With ECD, the incidence of transient facial nerve injury is reduced from 20% to 8% and permanent damage is the same as SP (1.4% vs. 1.2%). Most of the surgical techniques deployed in ECD are also used routinely in traditional parotid surgery. The fundamental difference, however, is that in traditional surgery the threat of nerve injury drives the surgeon to find and proceed to a facial nerve dissection. The procedure of SP is an inaccurate description of the procedure. In contrast, ECD is not a nerve dissection but a tumour dissection procedure. The facial nerve is not routinely identified and explored in ECD; the act of leaving the nerve untouched within the parotid tissue reduces the incidence of transient nerve injury. The management of facial nerve injury applies to all parotid surgery; the transacted nerve should be repaired directly.

Sialocoele

Pressure dressings are important in reducing the incidence of sialocoeles and also in their management. If it occurs the incision line must not be reopened, it should be managed by regular needle aspiration, pressure dressings and salivary suppressants. Initially, it may require aspiration every 2 or 3 days but gradually the frequency will reduce and the sialocoele will resolve spontaneously over 10 days. Once the skin flap has re-attached to the parotid fascia and the pressure around the sialocoele is greater than that in the duct system, the saliva will preferentially flow down the duct.

Parotid duct injury

The transected parotid duct is treated the same for any type of parotid surgery. The duct should not be tied in the process of removing a benign parotid tumour unless it is absolutely essential. Tying the parotid duct increases the risk of sialocoele formation.

Frey's syndrome

The incidence of Frey's syndrome is less than 5% following ECD because the re-approximated parotid fascia is a barrier to neural infiltration compared to the incidence of 26% with SP.

Neuroma

Traumatic neuromas are more common with SP than ECD. This is due to the limited exposure of the parotid gland with ECD; the greater auricular nerve can be avoided in the dissection in over 60% of cases. There are no established ways of avoiding a traumatic neuroma once the nerve is transected. There are numerous anecdotes and suggestions in the literature but none proven to be effective.

Recurrence

The incidence of recurrent tumour following ECD is identical to that for SP about 1%–2% at 10 years. The median time to recurrence is 7 years.

Top tips

- Beware the small tumour; it may be low-grade malignancy.
- Check the clinical features of the tumour once the skin flap is raised to ensure that ECD is appropriate.
- Retract the parotid away from the tumour not the opposite.
- Never use any retractors on the tumour.
- If you cannot see through the tissue do not cut it, if you always do this, you will never cut a nerve.
- Do not work in a hole, extend the cruciate incision if needed. If it is getting difficult at one site in the dissection, then stop and move around the tumour and comeback later – it will be easier then.
- The Warthin's tumour is an ideal case for surgeons learning this procedure because it is not a true neoplasm so fear of recurrence is absent and most Warthin's tumours lie in the tail of the parotid, well away from the facial nerve. Remember to release the parotid and rotate it forward.
- Time spent applying an effective pressure dressing is well spent; it will reduce the likelihood of haematoma and sialocoele formation.
- If during an ECD, the surgeon becomes uneasy with the surgical environment then the operation can be drawn to a close by re-approximating the cruciform incision with 3 or 4 simple sutures. The surgeon can revert to the SP. Nothing is lost in this approach.

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48

Thyroidectomy

RUI FERNANDES and JACOB YETZER

CONTENTS

PRE-OPERATIVE CONSIDERATIONS

Thyroid lobectomy and total thyroidectomy are some of the most common head and neck procedures. Broadly speaking, these are performed for two basic reasons – either there is a confirmed or high enough suspicion for pathology to merit surgical removal or the patient suffers from the overall size of the gland. The latter may cause compressive symptoms or disfigurement leading the patient to seek surgical care.

In cases of pathology, relevant workup should be done including fine needle aspiration biopsy and imaging including ultrasound, computed tomography (CT) or thyroid nuclear scans. Having an accurate diagnosis is helpful, though not always possible, in determining the specific procedure to be done as well as the management of regional nodes. Patients undergoing thyroidectomy should also have basic biochemical workup for thyroid function. Those with overactivity should be medically controlled prior to surgery and should be offered the options for complete medical management where appropriate. Patients who have compressive symptoms or potential airway compromise should have careful pre-operative planning with an anaesthetist adept at airway management including fibre-optic techniques.

RELEVANT ANATOMY

The thyroid gland is a prominent bilobed endocrine gland which on average weighs approximately 20 g and occupies the space between the thyroid cartilage and fifth to sixth tracheal rings just deep to the strap muscles. It has a tenuous capsule around the entire gland, which is surrounded by the deep visceral fascia of the neck. Embryologically, this structure arises at the foramen cecum at the tongue base from the endodermal layer of the first and second pharyngeal pouches. It descends to the adult position in the neck by the sixth to seventh week of gestation. The proximal tract normally degenerates, but in cases when it does not, a thyroglossal duct cyst may arise along this path. Occasionally the thyroid fails to fully descend in the neck and ectopic thyroid tissue may be found anywhere along the course of the thyroglossal duct from the tongue base down to the hyoid bone.

The vascular supply to the thyroid gland is composed of paired superior and inferior thyroid arteries and veins and a lone middle thyroid vein on both sides. The superior thyroid artery arises from the external carotid artery and enters the superior pole from a supero-lateral direction along with the accompanying vein. The inferior artery arises from the thyrocervical trunk off of the first portion of the subclavian artery. On occasion, a thyroid ima vessel is present which enters the thyroid isthmus on its course from the subclavian artery. The middle thyroid veins enter laterally from the internal jugular system and have no accompanying arterial supply.

Anatomically relevant nerves in the region include the bilateral external branch of the superior laryngeal nerve, which provides motor function to the cricothyroid muscle, and the recurrent laryngeal nerves, which are responsible for the remaining intrinsic laryngeal muscles. Both of these are branches of the vagus nerve. The external branch of the superior laryngeal nerve travels with the superior pole vessels to enter the cricothyroid muscle and is not always visualized during surgery. As a result of their being dragged inferiorly during embryologic development, the recurrent laryngeal nerves follow a more circuitous route. The left recurrent laryngeal nerve (RLN) courses around the ligamentum arteriosum to approach the larynx from below along the tracheo-oesophageal groove, whilst

the right side travels around the subclavian artery after branching from the vagus. In less than 1% of individuals, a non-recurrent nerve is present on the right side secondary to atypical formation of a retro-oesophageal subclavian artery.

Finally, the parathyroid glands must be acknowledged during surgery of the thyroid. Residing on the posterior surface of the thyroid gland, they each weigh approximately 50 mg and reside on the posterior surface of the thyroid gland. The majority of the population has four parathyroids and some have more. Identification requires attentive searching, as they are quite small and can blend in, especially in a bloody field. The parathyroid glands are usually of caramel colour that differs from adjacent fatty tissue. The superior parathyroids are derived from the fourth pharyngeal pouch and are usually found at the level of the cricoid cartilage. The inferior counterparts are somewhat more variable given their greater distance travelled during development due to their origin at the third pharyngeal pouch.

OPERATIVE TECHNIQUE

Setup (Figure 48.1)

Prior to bringing the patient to the operating room, marking is done in the pre-operative area with the patient standing upright in order to aid in identification of the neck crease that most easily allows the incision to heal whilst permitting sufficient surgical access. The patient is then brought to the operating room positioned supine. With administration of general anaesthesia, the patient is orally intubated with a neural integrity monitor (NIM) tube. The anaesthetist typically uses an endoscopic-assisted technique in order to allow the surgeon to confirm accurate placement of the tube's monitoring surfaces. The NIM tube is recommend in all cases to aid in the preservation of the recurrent laryngeal nerve, but by no means can it be considered a panacea for identifying or preserving the nerve. Anatomic identification and strict technique are the primary means by which the nerves ought to be identified and protected. The continuous neural monitoring provides an adjunct with which to confirm security of this vital structure.

Once the patient is intubated and all monitors applied, the patient is positioned with the neck extended using either a soft shoulder roll or positioning the head of bed in an extended position. Avoid overzealous neck extension or a position that leaves the patient positioned with the patient's head unsupported. In patients with a large body habitus, especially when combined with a short, thick, neck, it can be helpful to tape down the chest with foam tape applied to the table with a caudad vector. Also, during tucking of the arms, gentle traction can be applied inferiorly to bring the shoulders down and provide better exposure of the neck.

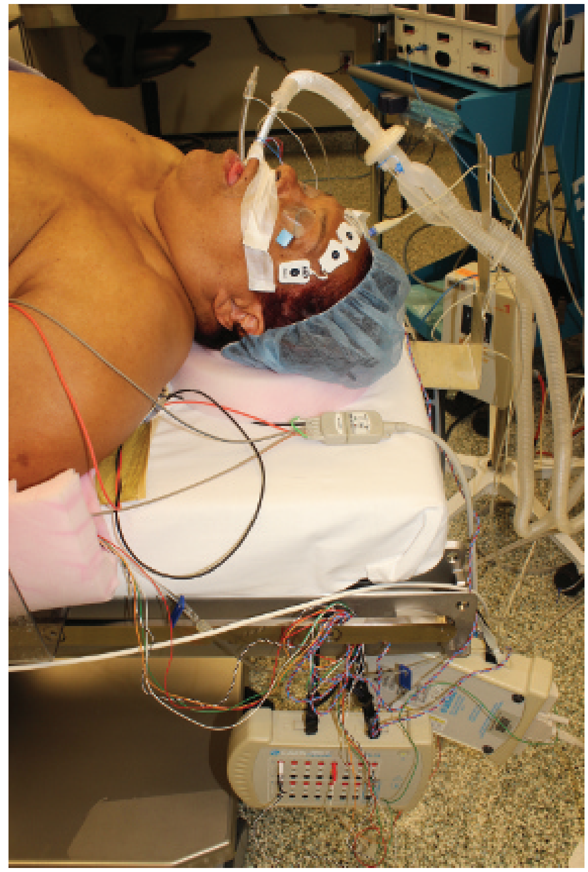

Figure 48.1 Nerve monitor apparatus is set up and monitored by a technician at a console in the operating room.

Exposure

The thyroidectomy patient population can often be quite image conscious particularly with regards to neck scars. Exposure is therefore limited to what is necessary. Usually a 4–5 cm horizontal incision set symmetrically between the sternocleidomastoid muscles is sufficient. For small volume glands, incisions as small as 3 cm will accommodate the procedure and generally results in a more pleasing scar to the patient (Figures 48.2 and 48.3). As mentioned, the marking is done pre-operatively and placement within a favourable neck crease is now confirmed with the neck in extension. A Colorado tip electrocautery on a low setting is used to make the incision. The use of the electrocautery ensures haemostasis. A continuous smooth and expeditious movement minimizes thermal injury. Sub-platysmal flaps are raised superiorly to the thyroid notch and inferiorly to the sternal notch. Traction sutures are used to hold back the flaps as they provide reasonable mobility during later dissection in contradistinction to large, rigid retractors.

Gland dissection

The superficial fascia is divided between the anterior jugular veins and the midline of strap muscles is identified.

Figure 48.2 Incisions as small as 2.5 cm may be used for smaller volume glands and when the patient has favourable neck anatomy.

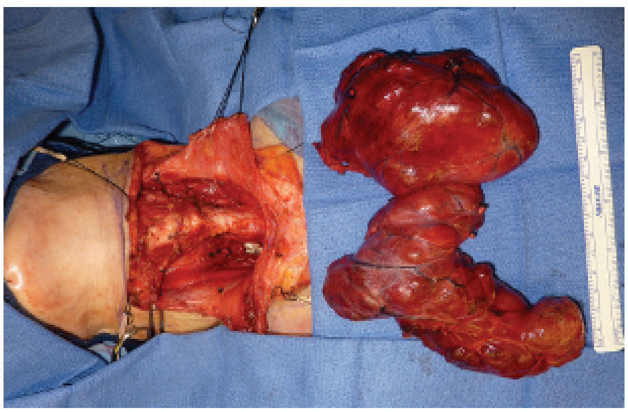

Figure 48.3 A traditional Kocher-style incision extending from sterno-cleido-mastoid (SCM) to SCM may be required for large goiters. Horizontal division of the strap muscles in these cases will also facilitate access.

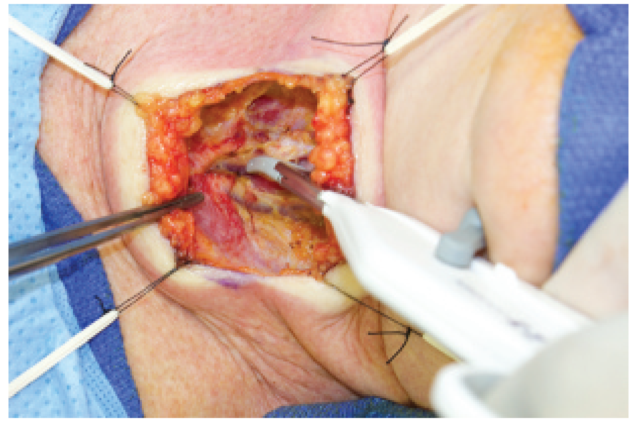

Figure 48.4 After sub-platysmal flaps have been raised, they are retracted with sutures. Ligasure is used to divide the strap muscles at midline.

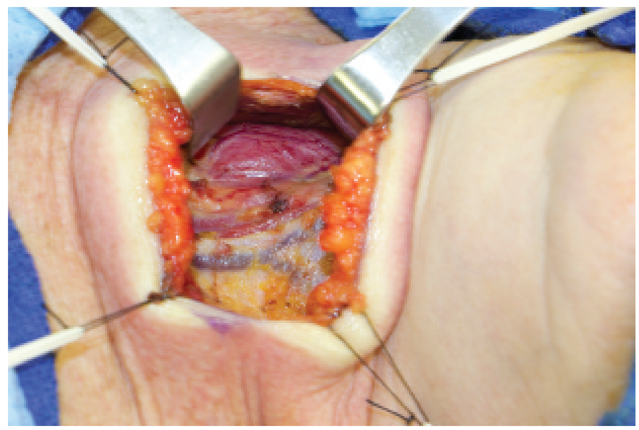

Figure 48.5 The right thyroid lobe is exposed with blunt dissection aided by retractors providing counter traction in a supero-lateral fashion.

The middle cervical fascia, which encapsulates the strap muscles, is divided in order to expose the underlying thyroid. The use of Ligasure dissection helps to speed this portion of the procedure and render the dissection bloodless (Figure 48.4). The sternohyoid and sternothyroid strap muscles are then dissected off the gland. In rare cases transection of the strap muscles are required to facilitate exposure (Figure 48.3). The vast majority of time, the thyroid can be easily exposed by gentle retraction by tenting up the muscle in a supero-lateral direction whilst simultaneously retracting the gland using Kittner dissectors in a motion that rolls the gland out of the wound (Figure 48.5). This traction-counter traction reveals the layer of visceral fascia as a 'fluff' of tissue that can be mostly bluntly dissected off the thyroid capsule. Attention should be paid to the superior aspect where muscle is not as easily lifted free in order to ensure complete dissection of the gland towards the superior pole.

Capsular dissection is continued widely in order to mobilize the gland. The middle thyroid vein (or veins) are usually identified early on in the dissection and can be ligated with ties or surgical clips. The specific sequence of the operation progresses and any tethering vessels that follow can be directed by how the gland dissection and can be ligated with ties or surgical clips. It is particularly helpful to allow an element of improvisation in cases of large goitres when visibility is limited. However, by freeing the gland broadly with continuous wide dissection eventually the next logical step presents itself. For most cases, though, the superior pole is the first area to be addressed. With the muscle freed from the gland, the superior pole of the can be visualized and mobilized with a combination of blunt dissection and use of bipolar electrocautery to divide small vessels and attached fascia tethering the thyroid. Extra attention is paid to make a clean dissection between the superior thyroid and the cricothyroid space. A pair of Kittner dissectors can then be used on either side of the superior pole to bring the vessels easily into view. A clear dissection of the superior artery and veins before ligating them will help to prevent injury to the external branch of the superior laryngeal nerve. Use of

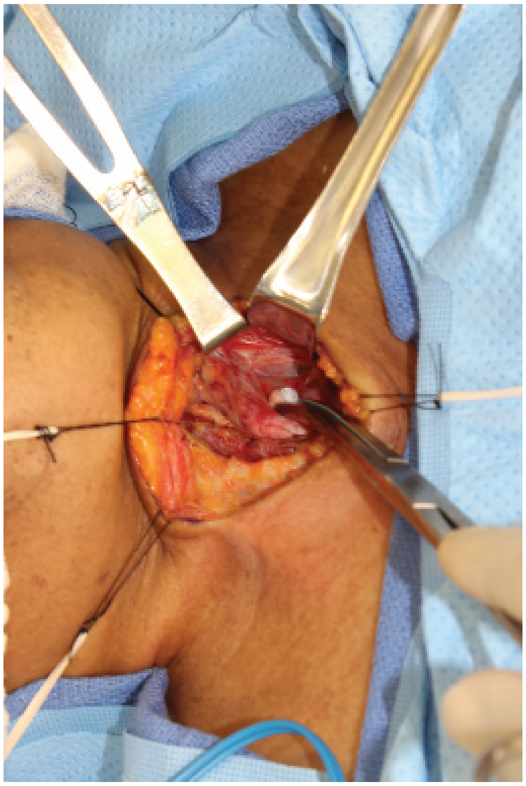

Figure 48.6 As dissection progresses, the gland (left lobe shown here) is continuously maneuvered 'up and out' using Kittner dissector or by hand.

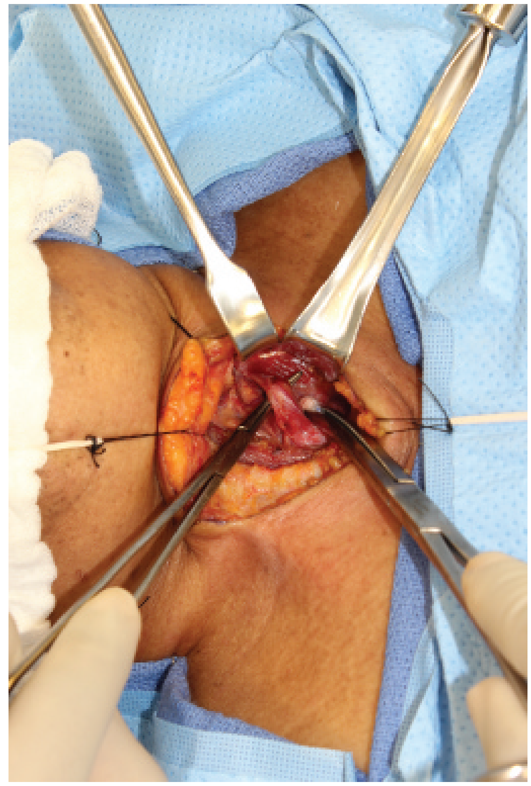

Figure 48.7 The gland is retracted inferiorly and the superior pole vessels are ligated using silk suture passed under the vessels in this case.

a right-angle dissector is useful in aiding the visualization and ligation of the vessels.

At this point, the dissection is brought inferiorly. Continuous use of the bipolar for fine dissection and gentle blunt dissection is used. It is important to avoid picking up the gland itself, as this almost surely will cause bothersome, persistent bleeding, which impedes progress. As the gland begins to mobilize, a portion of it can be brought out of the wound bed and retracted gently by hand in order to aid in further dissection (Figure 48.6). The superior parathyroid glands can usually be identified as the dissection is carried inferiorly. These tend to pop out clearly if strict capsular dissection is done. With the use of fine forceps, the fascia of the parathyroids can provide traction for dissection off the thyroid gland without undue trauma to the parathyroids or their vascular supply. It is especially crucial to look for and preserve any parathyroid glands in cases of total thyroidectomy. If there is any concern based on the course of dissection or colour change in these glands, consideration should be given to autotransplantation.

The inferior pole can be approached next. There are usually multiple branches of the inferior pole vessels entering the gland and therefore it is important to carefully dissect each to achieve a clean field (Figures 48.7 and 48.8). In similar fashion to the superior vessels, a right-angle dissector is used to cleanly dissect these vessels before they are ligated. This will prevent inadvertent injury to the recurrent

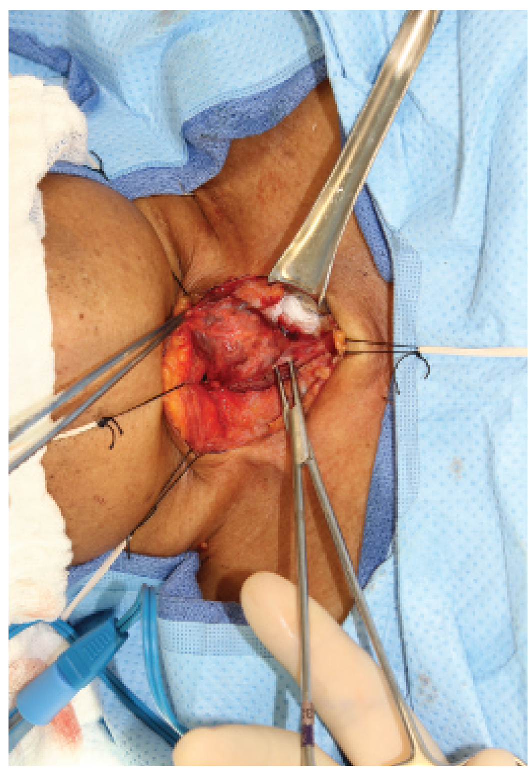

Figure 48.8 The inferior pole vessels are shown being exposed and ligated with silk suture. Alternatively, these can be taken with stainless steel clips or haemostatic devices.

laryngeal nerves. The median portion of trachea can then be exposed inferiorly to establish a plane of dissection.

The recurrent laryngeal nerve is identified prior to proceeding with the lateral-to-medial dissection. On the left side, the nerve tends to follow a fairly predictable course paralleling the tracheo-oesophageal groove as the nerve courses superiorly towards the larynx after wrapping around the ligamentum arteriosum. The right side, on the other hand, tends to approach the larynx from a more inferolateral direction after passing under the ipsilateral subclavian artery. Additionally, a non-recurrent nerve is present in approximately 0.5% of the population on the right side. Volumes have been written on the anatomic landmarks for identification of the RLN. We find that the nerve can generally be found within approximately 10 mm of the inferior parathyroid gland. Alternatively, the nerve can be searched for distally near the cricothyroid joint as it enters the larynx. This knowledge, along with careful blunt dissection will allow the RLN to be found. Rarely is blind nerve probing with the neural monitor necessary. In cases where the NIMs monitor is used, confirmation of the position of the nerve can be done by using the nerve probe.

At this point, the only attachment remaining in order to free the gland is Berry's ligament. This structure must be divided to free the thyroid from the trachea. Gentle medial traction of the gland is provided. The key is to avoid pulling too enthusiastically. This can cause two problems. First, the nerve can be pulled up within the fascia and become very difficult to differentiate from fascia as it arborizes distally. Second, aggressive traction makes it more likely for the smaller vessels in the area to tear and bleed, which compounds the problem of visually tracking the nerve. Thus, we dissect the tenuous Berry's ligament using bipolar cautery and right angle dissector where necessary to maintain a plane above the RLN. The dissection here is brought towards the trachea and completed by joining the plane inferiorly where the tracheal fascia has been exposed previously. Dissection is finished by freeing the thyroid isthmus towards the contralateral paramedian trachea.

If a total thyroidectomy is being performed, the opposite lobe is dissected at this point. The previously dissected lobe can be delivered from the neck and used to apply traction for the opposite side. Alternatively, it can be tucked back in situ in order to provide an unobstructed view as dictated by surgical progress (Figure 48.9).

For closure, a small suction drain is placed deep to the strap muscles. The muscles are then re-approximated with two to three resorbable sutures. The platysma is sutured with 3-0 Vicryl sutures and skin closure is achieved with 5-0 monofilament subcuticular sutures. A single Steri-Strip applied along the wound provides a neat closure and comes off painlessly after several days.

Post-operative management

Lobectomy patients may be managed either as outpatients or admitted for 24 hours depending on patient preference.

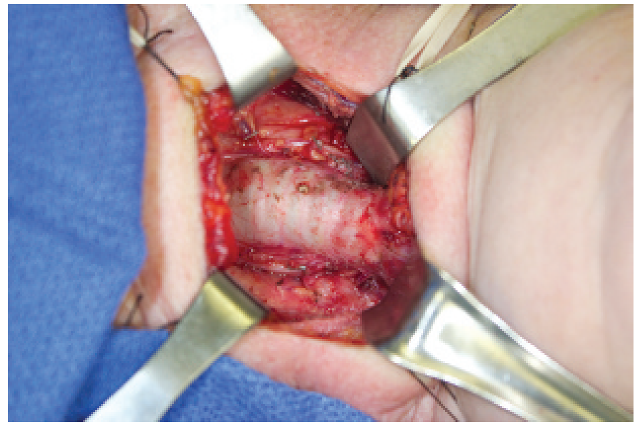

Figure 48.9 The gland has been completely removed in this image with the surgical bed revealing intact RLN bilaterally. These can be confirmed using nerve monitoring.

For total thyroidectomies, patients are admitted for 24-hour observation. During that time, they are monitored continuously for any airway problems or vocal changes that may indicate injury to the recurrent laryngeal nerve. Also, oral calcium is provided at a dosage of 3 g elemental calcium daily. The patients are also discharged on this dosage for 1 week. During the hospital stay, calcium levels are monitored every 8 hours. Every patient has an endocrinology consultation as an inpatient as well in order to establish continuity of care with the appropriate provider.

Thyroglossal duct cyst

Given the associated anatomy with thyroidectomy, a brief discussion of management of thyroglossal duct cysts is given here. As mentioned, this benign lesion will present either in adults or children as a soft, mobile, midline mass that moves superiorly during swallowing. It results from persistence of the tract as the thyroid descends from the foramen cecum during embryologic development. The treatment is surgical excision of the duct, known as the Sistrunk procedure.

Pre-operative workup is relatively straightforward. Testing of the cyst itself is not commonly required as the thyroglossal duct cyst is a clinical diagnosis (Figures 48.10 and 48.11). If there is an acute infection of the cyst, then medical management with antibiotics to resolve the inflammation is indicated. Also, the presence of normal thyroid tissue should be confirmed by ultrasound or some other means of imaging to ensure that the patient's only thyroid tissue does not reside within the cystic tract to be excised, thus rendering the patient hypothyroid.

Sistrunk procedure

The operative setup for the Sistrunk procedure mirrors that of the thyroidectomy with regards to patient positioning. The NIM monitor need not be used during this

Figure 48.10 Lateral view of a small thyroglossal duct cyst and the corresponding sagittal computed tomography (CT) image.

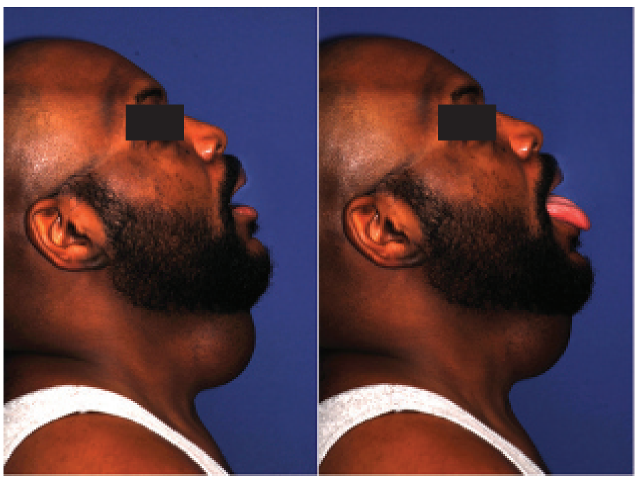

Figure 48.11 This patient with a large thyroglossal duct cyst demonstrates the elevation of the mass during tongue elevation due to its epithelial tract associated with the hyoid.

operation, as the recurrent laryngeal nerves should not be approached. A horizontal incision is made through skin over the prominence of the mass paralleling the hyoid bone. The incision is deepened to a sub-platysmal layer. Care must be taken here as the mass may widen the platysmal diastasis leaving only a thin layer of fascia covering the cyst. Every effort is made to avoid rupture of the cyst since this will make complete excision more difficult. The sub-platysmal flaps are elevated superiorly and inferiorly in order to allow exposure of the entire mass.

The midline is identified and the strap muscles are divided at this point and finely dissected off the cyst wall (Figure 48.12). Lateral and inferior dissection is performed first in order to clearly define the surgical plane and begin to mobilize the specimen. Next, the hyoid gland is palpated and electrocautery used to cut down on the medial portion of the bone (Figures 48.13 and 48.14).

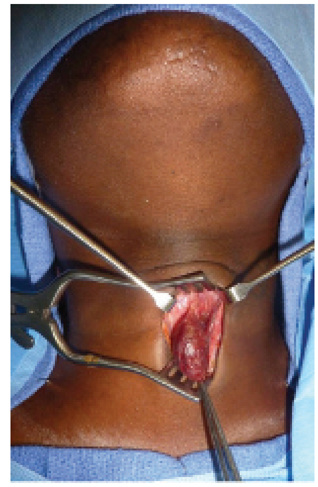

Figure 48.12 Initial dissection of the thyroglossal duct cyst with exposure of the cyst deep to the infrahyoid strap muscles.

Figure 48.13 Sistrunk procedure showing dissection of the epithelial tract towards the hyoid which has been exposed in order to include the central portion in the specimen.

The medial portion of the sternohyoid and thyroid hyoid as well as the suprahyoid muscles is divided in order to expose the hyoid for osteotomy. Division of the midline segment of hyoid is a mandatory part of the procedure as the cystic tract can be tenuously fused to the posterior surface. The risk of recurrence is elevated if the hyoid is not taken. In addition, removal of the midline hyoid allows for easier retraction and a more thorough superior dissection. A periosteal elevator is used to dissect soft tissue off the hyoid circumferentially such that a 2–3 cm portion may be osteotomized. The hyoid immediately adjacent to the tract should not be dissected along on its deep margin. Rather, the deep sub-periosteal dissection should only be performed lateral to the tract in order to avoid interruption of the lining. At this point, the bone cut can be made with a heavy scissors or fine fissure bur.

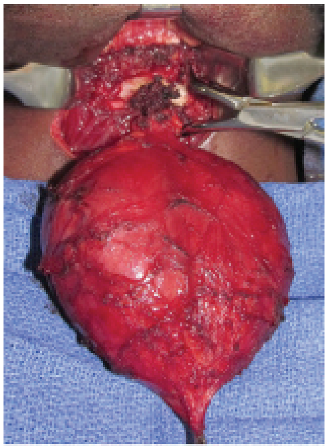

Figure 48.14 Intraoperative images of the second patient demonstrates the dissection of a large thyroglossal duct cyst.

Once the osteotomy is complete, the specimen is further mobilized and dissection continued using bipolar dissectors along the plane. Exposure of the most superior aspect of the dissection can be aided in several ways. A Kocker clamp may be applied to the hyoid in order to provide traction and the bulk of the specimen can be delivered through the neck incision. This manoeuvre is facilitated by bimanual manipulation with one finger placed transorally at the tongue base. This should reveal whatever remaining tract remains up to the foramen cecum. After the entire lining is dissected, it is divided at the base of tongue and delivered as one specimen.

Closure is achieved in a fashion similar to the thyroidectomy. Strap muscles are re-approximated with resorbable sutures and layered closure is performed. Depending on the size of the cyst and anticipated dead space, a suction drain is placed until output is minimal. Post-operatively, patients may be admitted for 24-hour observation or managed as outpatients.

Top tips

Always evaluate and record pre-operative vocal cord mobility.

- Maintain the dissection outside the thyroid capsule to avoid excessive bleeding.
- Avoid excessive retraction of the lateral thyroid lobe when dissecting one the recurrent laryngeal nerve to avoid traction injury to the nerve.
- Delay definitive surgery for an infected thyroglossal duct cyst, await resolution of the infection.
- Thyroglossal duct cysts are not always precisely in the midline.
- Dissection of the duct tract towards the foramen caecum can be difficult as a distinct duct is rarely seen rather a cone of tissue should be excised.
- Before excising, ectopic thyroid tissue always establish the presence of functioning thyroid tissue elsewhere.

SUGGESTED READINGS

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SECTION VI

VASCULAR LESIONS

49

Treatment techniques, surgery and sclerosants

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CONTENTS

CLASSIFICATION OF VASCULAR ANOMALIES

The management of vascular anomalies has been confusing for surgeons because of an illogical and largely descriptive nomenclature that has reflected a lack of understanding of the biology of these lesions.

In 1982, the clinical behaviour and endothelial cell characteristics of vascular lesions were analyzed and an elegantly simple biologic classification system was proposed (Table 49.1). Vascular lesions were categorized as either haemangiomas or vascular malformations. Haemangiomas are tumours of endothelial cell origin and vascular malformations are structural abnormalities of blood vessels lined by normal endothelial cells (Table 49.2).

Table 49.1 Classification of vascular anomalies.

Tumours	Malformations
Haemangioma (infantile)	**Slow flow:**
Haemangioendothelioma	Capillary (CM)
Angiosarcoma	Lymphatic (LM)
	Venous (VM)
	Combined (CLM, CVM, LVM, CLVM)
	Fast flow:
	Arterial (AM, AVM, AVF)

Abbreviations: AM, arterial malformation; AVF, arterial venous fistula; AVM, arteriovenous malformation; CLM, capillary-lymphatic malformation; CLVM, capillary lymphatico-venous malformation; CVM, capillary venous malformation; LVM, lymphaticovenous malformation.

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PRINCIPLES OF MANAGEMENT

The first and most crucial step in evaluating a patient with a maxillofacial vascular anomaly is to determine whether the vascular lesion is a tumour or a malformation.

Newborn, infant and childhood photographs are reviewed with the parents to determine if the lesion was present at birth, as well as the rate of growth. History and physical examination provide an accurate diagnosis in more than 90% of patients with vascular lesions.

Magnetic resonance imaging (MRI) with gadolinium is the standard, initial imaging technique for diagnosis of vascular anomalies.

INFANTILE HAEMANGIOMA

The standard of management is observation, reassurance of the parents and excision of the fibrofatty tissue and abnormal skin after involution when the child is 8–12 years of age. It may be helpful, in cases where there is family pressure for immediate operation, to show the parents photographs of a similar tumour during proliferation and involution. For psychological reasons, a well-localized,

Table 49.2 Clinical characteristics of vascular anomalies.

	Haemangioma	Vascular malformations
Initial presentation	Usually not present at birth[a]	Present at birth May not be obvious
Growth	Rapid proliferation in the first 4 weeks of life. Proliferating phase may last until 12 months	Grow proportionately with the patient
Involution	Slow regression at 12 months to 12 years (involuting phase)	No regression Persist throughout life
Hue	Superficial: bright red Deep: bluish or no discolouration Involuting phase: the skin becomes pale, particularly in the centre of the lesion Involuted phase: (after 12 years) normal skin is restored in 50% of children. The remainder have some laxity, discolouration, scarring, telangiectasias or a residual fibrofatty mass	Capillary: pink to red Venous: bluish Lymphatic: colorless Macrocystic: transilluminate Microcystic: irregular surfaces, clear or dark haemorrhagic bullae and vesicles (salmon eggs) AVM: pink or no skin discolouration
Palpation	Firm or rubbery Non-compressible Cannot be emptied of blood with compression No pulsations Involuting phase: softer on palpation	Capillary: flat Venous: soft, compressible, refill rapidly Lymphatic: soft AVM: firm, warm and pulsatile
Intraosseous location	No[b]	Yes
Secondary bone involvement	Bony distortion[c]	35% involve the bone directly Slow flow: bone overgrowth High flow: bone destruction

[a] A pale spot or telangiectatic or macular stained area may be present at birth at the site where the haemangioma will proliferate.

[b] The intra-osseous lesions called haemangiomas in the oral surgical literature are most commonly low flow venous malformations. However, primary vascular tumours, such as haemangioendothelioma, haemangiopericytoma and angiosarcoma do occur in bone.

[c] For example, depression of the outer cortex, nasal deviation, orbital enlargement and minor hypertrophy of the maxilla or mandible are occasionally noted in the presence of, or after involution of, a large cutaneous facial haemangioma.

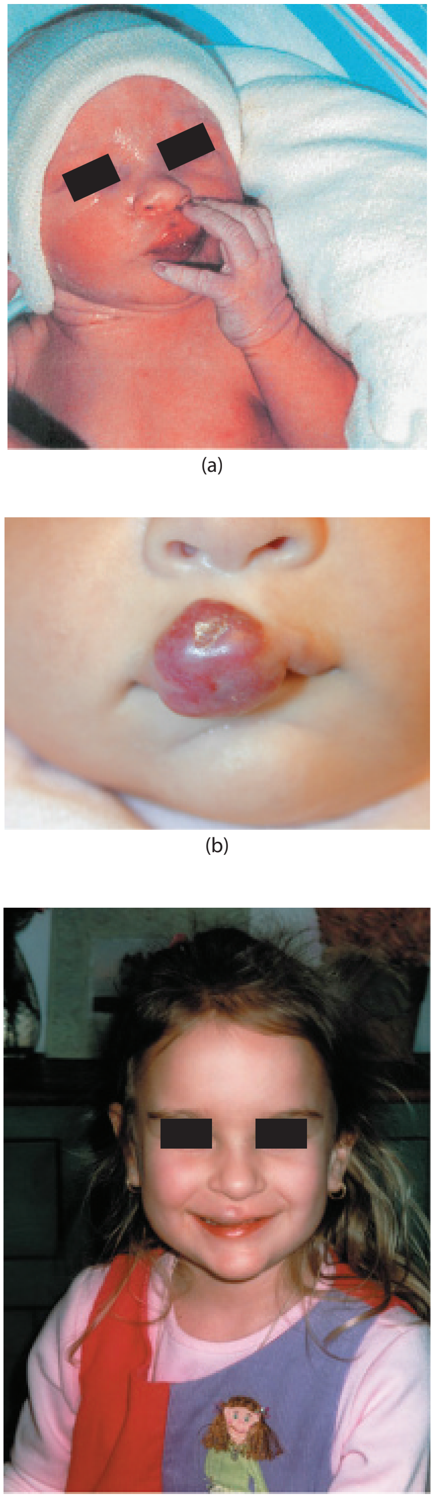
disfiguring haemangioma can be excised, even if not fully involuted, before the child starts school.

Indications for treatment

- Well-localized tumour
- Ulceration
- Bleeding
- Airway obstruction (subglottic)
- Lesion interfering with vision (upper eyelid haemangioma)
- Abnormal skin and fibrofatty tissue
- Distortion of the facial features

Treatment options

- Intra-lesional steroids. For haemangiomas less than 2 cm in diameter, serial intra-lesional steroid injections (3–5-mg/kg triamcinolone) are performed through a 25-gauge needle. Usually, three to five injections at 6–8-week intervals are required to accelerate involution (Figure 49.1). Intra-lesional injections can be used for upper eyelid haemangiomas with caution.
- Systemic corticosteroids (for destructive, function impairing or life-threatening lesions). Prednisolone, at a dosage of 2–3 mg/kg per day, is administered once a day for 2 weeks. If there is a response, the drug is continued and slowly tapered and withdrawn at about 10–11 months of age. Haemangiomas in the involuting phase do not respond to steroids.
- Interferon alpha-2a or -2b or vincristine (in cases unresponsive to corticosteroids). Interferon is administered daily, at a dosage of 3 million units/m^2 subcutaneously. Transient side effects of interferon therapy include fever and a flu-like syndrome at the start of treatment (most patients), neutropenia, skin necrosis and skin rash. Interferon can adversely affect the central nervous system in infants by producing spastic diplegia. This is potentially reversible upon cessation of therapy; careful clinical observation is required during treatment.
- Treatment with B-blockers such as propranalol has been shown to decrease the size of haemangiomas or lead to total regression of the lesion. Recommended regimen is 1-2 mg/kg once per day per os for 6-12 months. In cases where the lesion disappeared 2 months after the initiation of propranalol have been reported. Side effects include nausea, symptomatic blood pressure decrease, somnolence, asthma and gastrointestinal symptoms. Use of propranalol for the treatment of infantile haemangioma was approved by the FDA in 2014.



(a) (b) (c)

Figure 49.1 Infantile haemangioma. (a) A newborn infant with normal facial appearance, except for a small discolouration at the lower end of the philtral column. (b) At 4 months of age, the lesion shows rapid growth (proliferative-phase haemangioma) and superficial ulceration. (c) Frontal photograph at 6 years of age after three intra-lesional triamcinolone injections and excision at the involuting phase. (From Kaban LB and Mulliken JB., In Kaban LB and Mulliken JB [eds.], *Pediatric Oral and Maxillofacial Surgery*, WB Saunders, Philadelphia, 2004. With permission.)

- Surgical excision (Figure 49.2). In 2002, the strategy of circular excision and purse-string closure for haemangiomas was introduced.
- Staged resection is often necessary for labial haemangiomas because they cause distortion in three dimensions. The mass is de-bulked by excising involved mucosal and submucosal tissue, usually in a transverse axis. Excision at the vermilion–cutaneous junction should be delayed, and vertical incisions on the skin should be avoided.

Complications

- Ulceration is common for infantile haemangiomas, especially for those on the lip. These ulcerated areas should be treated by frequent cleaning and application of topical antibiotic ointment. Occasionally, debridement is required, followed by dressing changes. If the ulcer fails to heal with local measures, treatment with steroids is indicated.
- Bleeding can usually be controlled by local pressure. Embolization is rarely used for uncontrollable bleeding from deep, extensive haemangiomas.
- Steroid therapy may cause temporary growth retardation and decreased appetite.
- Large cutaneous haemangiomas can cause life-threatening congestive heart failure and anaemia.
- Thrombocytopenia due to platelet entrapment in large haemangiomas may cause bleeding. This is managed with steroid therapy. Platelet transfusions are not beneficial.

VASCULAR MALFORMATIONS

The first step in the care of a patient with a vascular malformation is to determine whether it is a slow- or fast-flow lesion. Complete resection is not possible in most cases, hence the possibility of uncontrollable bleeding during operation and the likelihood of recurrence. Occasionally, a well-localized, low-flow venous malformation (VM) of the jaw can be resected.

When slow-flow malformations without direct intraosseous involvement cause secondary bony distortion, orthodontic treatment and orthognathic surgical procedures can be carried out safely without the fear of excessive bleeding. Fast-flow lesions usually produce bony destruction and extractions or orthognathic surgery are prohibitively dangerous. In combined vascular anomalies, management is based on the characteristics of the predominant, deeper malformation.

Indications for treatment

- Increasing size and swelling
- Pain
- Bleeding

Figure 49.2 Circular excision of a haemangioma. (a) Involuting-phase haemangioma of the left cheek. A circular or ovoid incision is planned to include all the altered skin. In the proliferating phase, this includes damaged and ulcerated skin. In the involuted phase (as in this case), it includes atrophic skin and fibrofatty residuum. Minimal subcutaneous undermining is required. (b) A running, intra-dermal purse-string suture (4-0, 5-0 polydioxanone) is placed along the wound edge. (c) The suture is tightened to gather the edges and appose the wound margin. A gauze wick is placed if a small opening remains. The wound is covered with an absorbent dressing. Alternatively, the edges may be closed with percutaneous sutures in the axis of relaxed skin tension. (d) After several months of healing and remodelling, a decision is made to accept a small circular scar or to revise it. Clinical appearance of the patient 3 years post-operatively. (From Kaban LB and Mulliken JB., In Kaban LB and Mulliken JB [eds.], *Pediatric Oral and Maxillofacial Surgery*, WB Saunders, Philadelphia, 2004. With permission; Mulliken JB et al., *Plast Reconst Surg*, 109, 1544–1554, 2002. With permission.)

- Infection
- Macroglossia, dysarthria, dysphagia
- Feeding difficulties
- Bone distortion and malocclusion
- Airway obstruction

CAPILLARY MALFORMATION

Capillary malformations rarely present major problems for the oral and maxillofacial surgeon (Figure 49.3).

Treatment options

- *Pulsed dye laser:* 50%–75% of patients will notice improvement with between 2 and 20 sequential treatments (lightening of the lesion) under general anaesthesia or local anaesthetic cream.
- *Excision and skin grafts or flaps:* These are occasionally used in cases where the skin is very thick and the laser is unsuccessful.
- *Orthognathic surgery for skeletal overgrowth and distortion:* Maxillary and mandibular overgrowth is common

when there is staining of the overlying facial skin and mucosal lining. In patients with dentoalveolar distortion, osteotomies can be performed without fear of excessive bleeding (Figure 49.3).

Complications

- Thickening and nodularity of the lesion with ageing.
- Impaired vision. Involvement of the eyelids can be associated with elevated intra-ocular pressure and glaucoma (V1–V2 distribution).
- Recurrence after treatment.

VENOUS MALFORMATION

VM are the most common type of vascular anomaly. They occur in a spectrum, from isolated skin or mucosal varicosities to localized spongy masses, to large complex lesions permeated throughout tissue planes.

Treatment options

- Sclerotherapy: For large VMs with localized venous 'lakes', direct injection of absolute (100%) ethanol (sclerozing agent of choice in the United States) by an interventional radiologist is indicated. This requires general anaesthesia with real-time fluoroscopic guidance. Usually several sessions are necessary to shrink a large VM. Ethiblock (Ethicon, Hamburg, Germany), a radiopaque mixture of ethanol, contrast agent and amino acids, is also used in Europe. Small oral mucosal venous malformations can be sclerozed with injection of 1% sodium tetradecyl sulphate.
- Well-localized cutaneous VM can be excised.
- Resection marginal or segmental for well-localized bone lesions (Figure 49.4).

Complications

- Intermittent swelling, pain and fever are a common problem encountered in venous and combined lymphatic–venous lesions. Such lesions increase in size in relation to viral illness, trauma, adjacent (odontogenic) or intra-lesional infection and clotting. In these patients, it is difficult to distinguish between cellulitis, intra-lesional abscess, thrombophlebitis and phlebothrombosis. A local source for infection, such as carious teeth, peri-apical abscess or peri-coronitis must be excluded. Administration of the appropriate antibiotic (usually penicillin or clindamycin in the maxillofacial region) is begun. A drainage procedure is carried out only for an obvious abscess. Aspirin anticoagulation therapy may be useful in cases of venous malformation enlargement, if there are no local or systemic sources of infection and when there are tender phleboliths. In patients who respond to aspirin, indefinite administration of this antiplatelet drug to prevent intra-lesional clotting should be considered.
- Localized or systemic coagulopathy may result in major haemorrhage spontaneously or during an operation in large VMs. Disseminated intra-vascular coagulopathy can be caused by stasis and turbulence associated with the venous malformation. This is a consumptive coagulopathy. Prothrombin (PT) and partial thromboplastin times (PTTs) are often normal; thrombin time and levels of fibrin split products and fibrinopeptide may be elevated, with decreased fibrinogen and platelet levels. Heparin treatment is instituted when indicated and only when the coagulopathy is corrected are surgical procedures feasible. Another approach is to begin giving heparin followed by antifibrinolytic therapy with ε-aminocaproic acid. Failure to address this chronic consumptive coagulopathy will result in uncontrollable bleeding during a procedure.
- Systemic sepsis related to local infection with haematogenous spread. In these cases, hospital admission, blood cultures and intravenous antibiotic therapy are necessary.
- Recanalization of extensive venous malformation after sclerotherapy is a recognized occurrence. Repeat of sclerotherapy in this situation can be dangerous and cause local blistering, deep ulceration, full-thickness skin necrosis, nerve damage, haemolysis, haemoglobinuria and potential renal toxicity and cardiac arrest.
- Bleeding after teeth extractions is controlled by packing with pledgets consisting of microfibrillar collagen (Avitene, Davol, Warwick, RI) wrapped in oxidized cellulose sheets (Surgicel, Ethicon, Someville, NJ). These are held in place with 2/0 chromic catgut figure-of-eight sutures across the sockets. Extractions should be performed after sclerotherapy.
- Painful expansion secondary to injury, partial resection or endocrine changes (e.g. puberty, pregnancy, birth control pills). This may be the first evidence of the lesion.

LYMPHATIC MALFORMATION

Lymphatic malformations (LMs) are classified as macrocystic or microcystic. Macrocystic (called cystic hygroma in the past) occur below the mylohyoid muscle in the neck most frequently in front of the sternocleidomastoid muscle (Figure 49.5). Microcystic commonly involves the tongue, the floor of the mouth, the cheek, the lips and the mandible.

Treatment options

- Sclerotherapy with ethanol, OK-432 (attenuated *Streptococcus pyogenes*) or 1% sodium tetradecyl sulphate for macrocystic LM.
- Intra-lesional injections of bleomycin have been described with encouraging results.
- Small well-localized LM can be excised.

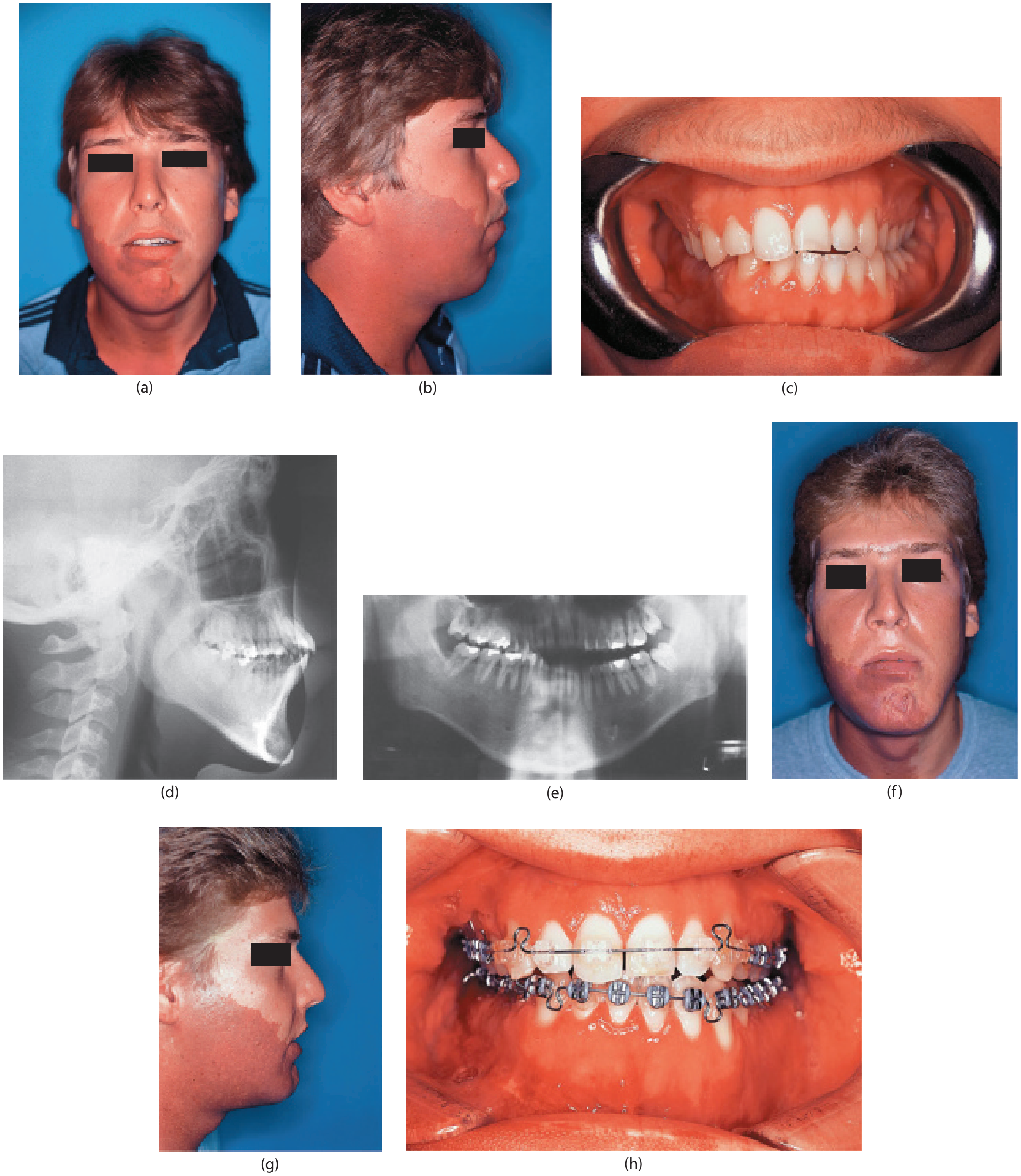


Figure 49.3 (a) Frontal and (b) lateral photograph of a teenage boy with dermal capillary malformation in the distribution of the second and third division of the trigeminal nerve. This is also a frequent finding in the Sturge–Weber syndrome that includes a capillary malformation of the V1 or V1–V2 trigeminal areas, choroidal vascular ectasia and leptomeningeal vascular anomalies. (c) Intra-oral photograph shows malocclusion due to excessive vertical growth of the maxillary alveolus on the right side. (d) Lateral cephalogram demonstrates the long lower face height and bimaxillary dentoalveolar protrusion. (e) Panoramic radiograph shows the hypertrophy of the mandibular body on the right side. Orthognathic surgery could be performed without risk of bleeding, since the malformation did not extend into the bone. (f) Frontal, (g) lateral and (h) intra-oral photographs after three-piece Le Fort I osteotomy, bilateral mandibular osteotomies and genioplasty. (From Kaban LB and Mulliken JB., In Kaban LB and Mulliken JB [eds.], *Pediatric Oral and Maxillofacial Surgery*, WB Saunders, Philadelphia, 2004. With permission.)

Figure 49.4 (a) Frontal ('worm's eye') view of a patient with venous malformation of the mandible. (b) Panoramic radiograph shows lytic changes in the bone. (c) Computed tomographic (CT) scan with contrast demonstrates the large malformation extending into the soft tissues. (d) Intra-operative photograph. Well-localized low flow vascular malformations can be treated with resection without the risk of excessive bleeding. (e) Panorex 1 year post-operatively and (f) submental view of the patient one year post-operatively. (From Kaban LB and Mulliken JB., In Kaban LB and Mulliken JB [eds.], *Pediatric Oral and Maxillofacial Surgery*, WB Saunders, Philadelphia, 2004. With permission.)

Figure 49.5 (a) Infant at 2 weeks of age with a left submandibular lymphatic malformation (LM). (b) Magnetic resonance imaging (MRI) T2 with gadolinium shows a macrocystic LM with homogenous enhancement that involves the anterior neck triangle. (c) Intra-operative photograph. Excision was performed through combined submandibular–intra-oral (sublingual) approach. The malformation extended to the floor of the mouth. During the course of the dissection, the lingual and hypoglossal nerves were identified and preserved. (d) Specimen. (e) Frontal; (f) submental and (g) intra-oral view at 9 years of age.

- Excision of cervical macrocystic LM with neck dissection approach. Complete excision may not be achieved as typically LMs in the neck extend deep into the parapharyngeal space with carotid artery and nerves adherent on the LM walls.
- Patients with large microcystic cervicofacial LM require serial, staged surgical excisions of the floor of the mouth and submandibular tissues.
- Orthognathic surgery after soft tissue excision to minimize recurrence and manage malocclusion and distortion of the maxillofacial skeleton (Figure 49.6).

Complications

- Bacterial infection (cellulitis) can cause sudden expansion of LM.
- Intra-lesional bleeding or bleeding from the irregular surface of microcystic LM in the morning upon awakening, possibly due to the increased venous pressure of sleeping supine.
- Airway obstruction when LM is located in the floor of the mouth or the tongue.
- Recurrence even years post-operatively.
- Sudden expansion often occurs coincidently with upper respiratory tract infection.
- Seroma after excision.

ARTERIOVENOUS MALFORMATION

A clinical staging system for arteriovenous malformations (AVMs) that is helpful in predicting the natural history has been introduced (Table 49.3).

The current strategy for management of AVMs is arterial embolization for occlusion of the nidus (centre of the AVM) of the malformation, followed 24–72 hours later by surgical excision. The surgical goal is complete resection of the AVM nidus and involved overlying tissue, although this is often not possible.

Treatment options

- Superselective arterial embolization is performed by an interventional radiologist. The principle is to obliterate the nidus of the malformation with embolization materials (Table 49.4). Thus, inflow to the AVMs is reduced with low risk of collateral flow development. Superselective embolization may be performed electively and followed by resection or it may be required as a life-saving procedure in the presence of acute bleeding. Proximal vessel embolization is contraindicated because of the rapid development of collateral flow to the nidus of the AVM. Post-embolization angiography is obtained to ensure reduced blood flow in the

(a) (b)

Figure 49.6 (a) Frontal, lateral and intra-oral photographs of a 13-year-old girl with a cervicofacial LM, mandibular prognathism and open bite, secondary to the progressive mandibular distortion. Lateral cephalogram and panorex show obtuse mandibular plane angle and anterior open bite. (b) Frontal, lateral and intra-oral photographs, lateral cephalogram and panorex 5 years post-treatment. The patient underwent resection of the LM, Le Fort I osteotomy, bilateral mandibular osteotomies and genioplasty. (From Padwa BL, In: Kaban LB and Troulis MJ [eds.], *Pediatric Oral and Maxillofacial Surgery*, WB Saunders, Philadelphia, 2004. With permission.)

Table 49.3 Schobinger clinical staging system for arteriovenous malformation.

Stage	Description
I (Quiescence)	Pink-bluish stain, warmth and arteriovascular shunting by continuous Doppler scanning or 20-MHz colour Doppler scanning
II (Expansion)	Same as stage I plus enlargement, pulsations, thrill, and bruit and tortuous, tense veins
III (Destruction)	Same as stage II plus either dystrophic skin changes, ulceration, bleeding, persistent pain or tissue necrosis
IV (Decompensation)	Same as stage III plus cardiac failure

Source: Reproduced from Mulliken JB et al., *Curr Probl Surg*., 37, 520, 2000. With permission.

Table 49.4 Embolization materials.

	Material
Temporary (resorbable)	Gelfoam Collagen Iodine oil
Permanent	Polyvinyl alcohol particles (e.g. ethylene-vinyl alcohol copolymer; Onyx, Micro Therapeutics, Irvine, CA, USA) Acrylic glue Silky thread Stainless steel Platinum coils

malformation and the AVM is examined for clinical improvement (skin colour, size, pulsation).

- Intra-osseous direct puncture of the AVM with platinum coils or other embolization materials may be used to supplement superselective embolization or in cases where further vessel embolization is not feasible (Figure 49.7).
- A 16-gauge needle trocar is placed directly through the bone or alveolus intra-orally using direct fluoroscopy.
- Placement of the trocar into the AVM nidus is confirmed by an arteriogram.
- Through the trocar, an 18-gauge catheter is placed using a guide wire.
- Embolization material is injected directly into the nidus through the catheter.
- This procedure can be repeated for multiple varices of the AVM.
- Post-treatment arteriogram is obtained.
- Partial or complete surgical resection of soft tissues or bone is performed 1–3 days after embolization. Embolization does not decrease the extent of resection. Hypervascularity makes haemostasis difficult intra-operatively, even after embolization. Intra-operative embolization must be available. All small arteries that supply the AVM should be ligated except the main, proximal arteries.
- Teeth extraction after AVM embolization (Figures 49.7 and 49.8). In patients with intra-osseous malformation in the tooth-bearing portions of the maxilla and mandible, teeth may be removed 24–48 hours after embolization insertion. The sockets are packed with Avitene and surgical pledgets and oversewn. Once the sockets heal and the wounds are completely mucosalized, the malformations often become quiescent and remain in Shobinger stage I. This is probably because the irritant of mobile teeth constantly being compressed by occlusal forces and perhaps chronic low-grade inflammation are eliminated.

Complications

- Massive blood loss during the operation may be life threatening. Even a single tooth extraction associated with an AVM can result in exsanguinating haemorrhage. Pre-operative embolization is performed to prevent this complication. Intra-operative bleeding is managed with urgent embolization or haemostatic materials such as Surgicel, Avitene, suturing and pressure. However, local haemostatic measures may be insufficient to control the bleeding. Prolonged intubation to secure the airway and blood transfusions may be necessary.
- Unfortunately, AVMs are not usually well localized and recurrence with expansion of vessels deep or at the periphery of the resection occurs in a high percentage of patients. For these patients, embolization is palliative and re-operation may not be feasible.
- Development of collateral vessels and flow to the nidus of the malformation occurs especially after proximal ligation or embolization.
- Absorption of embolization materials and recanalization of AVM.
- Extrusion of embolization materials through the mucosa intra-orally.

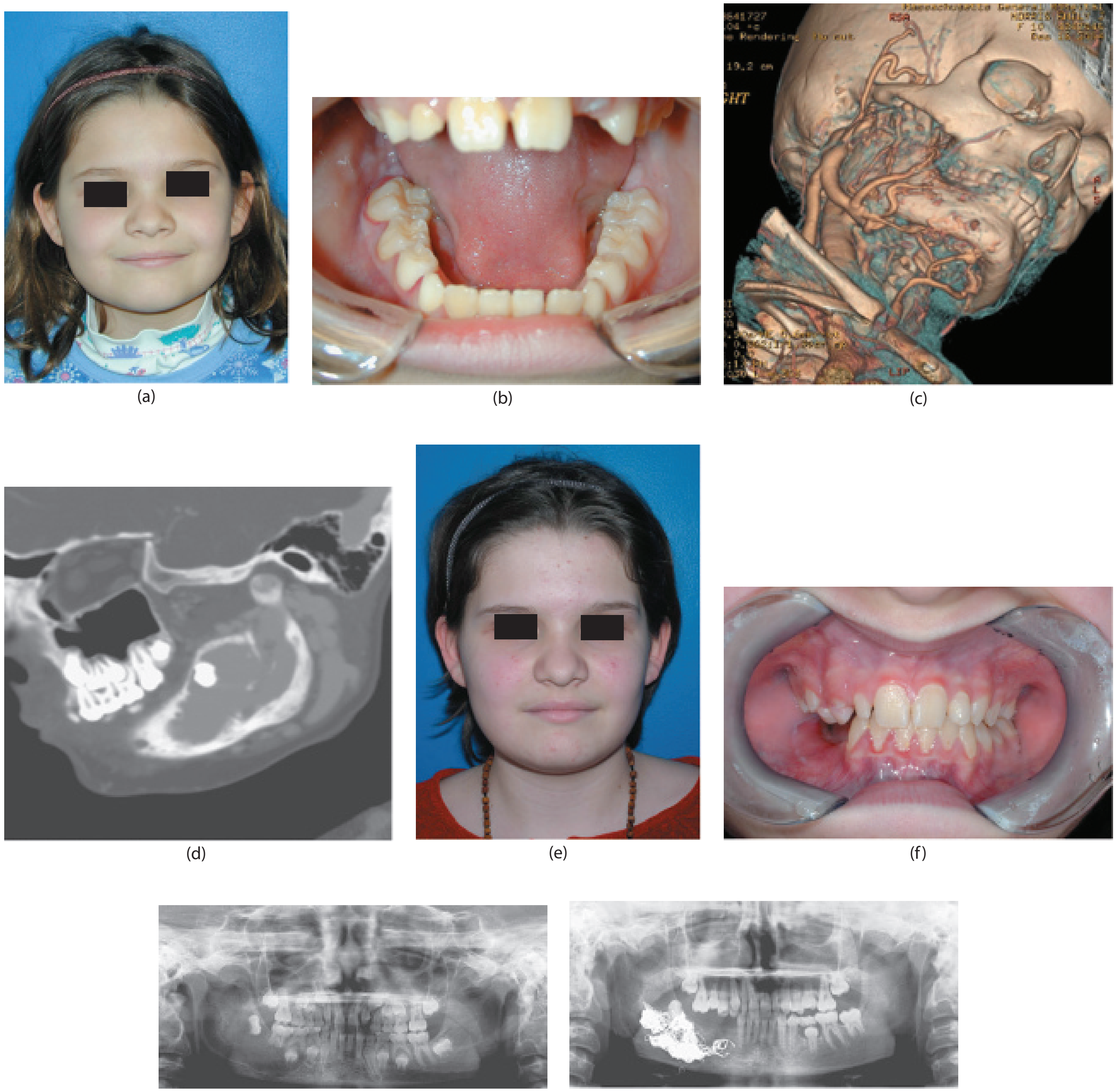


Figure 49.7 (a) Frontal and (b) intra-oral photographs of a 10-year-old girl with arteriovenous malformation (AVM) of the right hemimandible. The patient had noted swelling and intra-oral bleeding at the right mandible 2 months prior to her initial visit. Physical examination revealed enlargement of the right hemimandible, warmness of the area on palpation, but no tenderness and no discolouration of the overlying skin. A loud bruit was auscultated by stethoscope examination of the right submandibular region and a thrill was palpated. The teeth were mobile and depressible. (c) Three-dimensional computed tomography (CT) angiogram (3D-CTA) demonstrates the supply of the malformation from branches of the enlarged right (R) external carotid artery (R internal maxillary, R facial artery) and the left facial artery. No contribution of the right internal carotid artery is identified. Drainage of AVM (stage II–III) is via innumerable large venous varices that drain into an enlarged right internal jugular vein. (d) Sagittal section of CT scan shows the lytic AVM that involves and expands the right hemimandible including the ascending ramus. (e) Frontal and (f) intra-oral photograph 3 years after the patient's initial visit. She underwent multiple, urgent and scheduled embolizations with platinum coils and extraction of posterior mandibular teeth on the right side. (g) Panorex before intervention shows the large AVM that appears as a multi-loculated radiolucent lesion extending from the first premolar to the sigmoid notch. The mandibular 12-year molar is floating in the radiolucency and there is resorption of the 6-year molar. The second premolar tooth bud is also displaced and there is thinning of the inferior border cortex. (h) Panorex 3 years after the initial visit shows the intra-osseous coils and the filling of the cavity with bone. After the treatment, the AVM became quiescent (stage I).

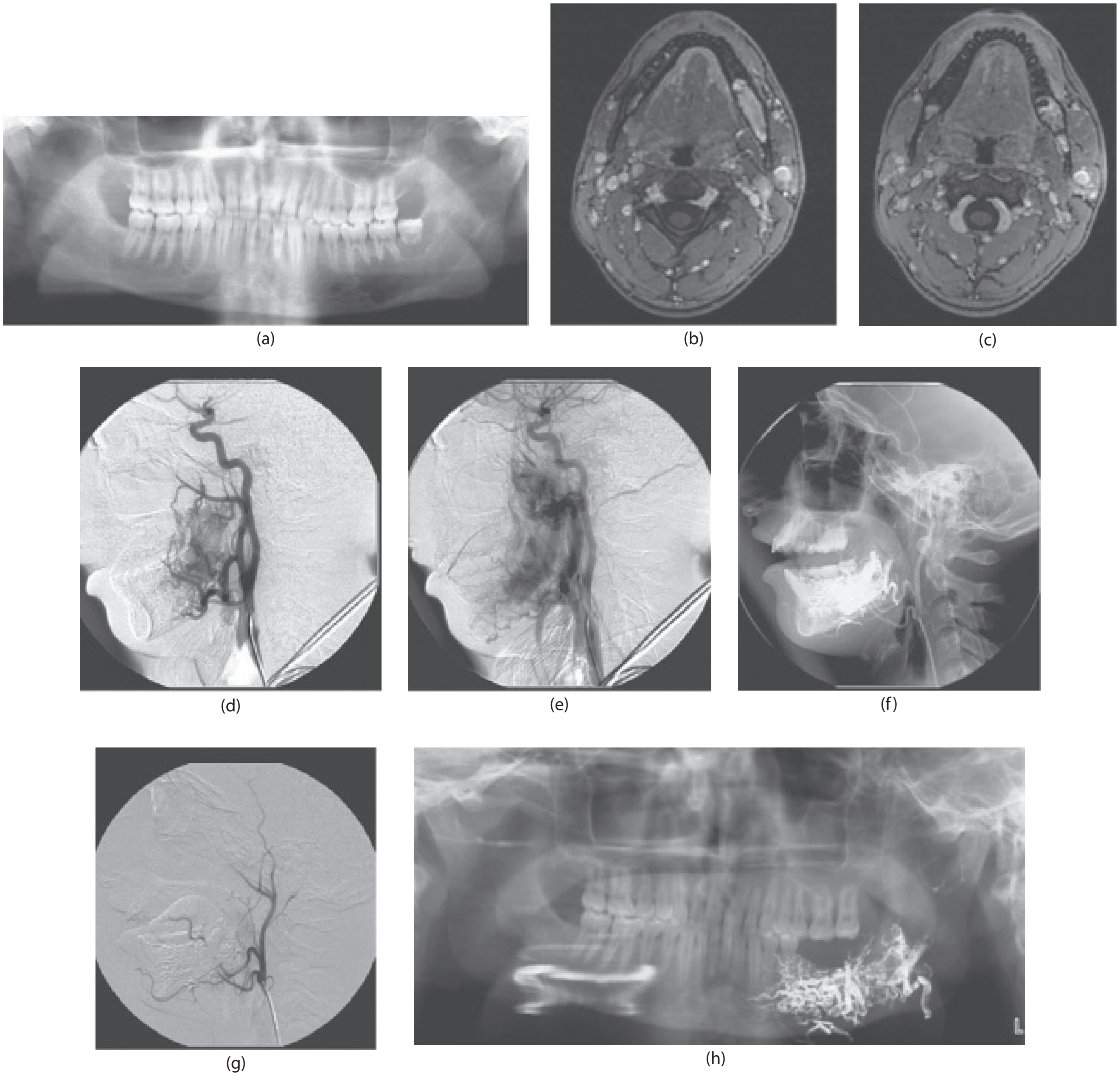


Figure 49.8 (a) Panorex of a 17-year-old boy who experienced excessive bleeding after an unsuccessful attempt to extract the left lower wisdom tooth. The procedure was aborted and the patient was referred to hospital. The radiograph shows a radiolucent area in the left mandible extending from the left first molar to the middle of the ramus above the lingula posteriorly. There is resorption of the third and second molar roots and the distal root of the first molar. (b and c) Axial sections of MRI T1 with gadolinium show a 36- × 12-mm septated lytic area in the left mandible with homogenous enhancement with flow voids indicating high-flow malformation. The patient was scheduled for transfemoral angiography and embolization under general anaesthesia. (d and e) Angiography of the left external carotid shows two large tangles of vessels, one over the angle of the mandible and the other over the condyle that interconnect with each other. Feeding arteries that supply the AVM are the lingual, facial and the first five branches of the internal maxillary artery (inferior alveolar artery, pterygoid artery, messeteric artery, buccinator artery and posterior superior alveolar artery). There is early venous drainage into the venous compartment of the mandible that drains into the external jugular vein. (f and g) Angiogram after embolization of the AVM nidus with 3.9-cc liquid Onyx (Micro Therapeutics, Irvine, CA). There is an onyx cast seen within the facial artery, the pedicles of the AVM and within the venous saccule of the mandible. Approximately 25% of the AVM has been embolized. During the procedure, excessive intra-oral bleeding was controlled with extraction of the lower left second and the third molars, packing the sockets with Avitene and Surgicel, suturing and pressure. Two months later, the lower left first molar was also extracted due to tooth mobility, pain and bleeding from its gingival sulcus. (h) Panorex 2.5 years post-embolization and extraction of three molars associated with the AVM shows the embolization material in the bony cavity. The malformation became and remains quiescent (Shobinger stage I) after treatment.

- Embolization of internal carotid branches can cause ischaemic stroke. General risks of angiography and embolization are death, bleeding, coma, damage to blood vessels and infection.
- Bleeding or ulceration of the overlying skin.

Top tips

- First, determine if the lesion is an haemangioma or a malformation.
- An intra-osseous vascular lesion is most frequently a malformation, not an haemangioma.
- In the case of haemangioma, determine whether it is proliferating or involuting.
- If malformation, determine slow flow versus fast flow.
- Sclerotherapy is effective for slow-flow vascular malformations, especially macrocystic LM and VM with large venous lakes.
- AVMs are treated with embolization and resection when possible, but recurrence rate is high. If dentoalveolar segment is involved, embolization and then removal of the teeth may result in long-term control with the lesion remaining in Shobinger stage I (quiescence).
- Patients with slow-flow lesions adjacent to bone can have skeletal deformity treated. With proper preparation there is little chance of life-endangering haemorrhage.

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Interventional radiology of the head and neck

JOHN S MILLAR

CONTENTS

INTRODUCTION

There has been rapid and widespread development of vascular interventional radiological techniques and devices over the past two decades and this chapter outlines their role in maxillofacial surgery.

First, an understanding of the classification and the role of imaging in the diagnosis of head and neck vascular malformations is essential. The various endovascular techniques that are employed in the treatment of these conditions will follow.

The importance of a multidisciplinary team approach to the management of these conditions must be stressed. In addition to oromaxillofacial surgeons and interventional radiologists, the expertise of numerous specialists, drawn from dermatology, diagnostic radiology, ENT ophthalmology, paediatrics, plastic and reconstructive surgery, pathology and neurosurgery will be required to deal optimally with these complex lesions. It goes without saying that close involvement of the patient in all decision-making is essential and psychotherapeutic support may be necessary as curative treatment may not be possible.

CLASSIFICATION

The classification of vascular anomalies of the head and neck, proposed by Mulliken and Glowacki in their paper of 1982, is widely employed. They categorized vascular anomalies according to endothelial cell characteristics and, although many more types of vascular lesions are recognized with the aid of modern immunohistochemical techniques, it has stood the test of time and represents a sound basis for the effective understanding and communication of these conditions (Table 50.1).

Haemangiomas are characterized histologically by high endothelial cell turnover. They are true neoplasms that usually present in infancy. They enlarge by cellular proliferation and exhibit a clinical life cycle which typically includes phases of proliferation, plateau and subsequent involution. They may be further characterized by cell markers (e.g. GLUT-1, merosin, Lewis Y) that are otherwise found only in human placental tissue. Most other vascular anomalies are properly termed 'malformations', which are characterized by normal endothelial cell turnover and abnormal gross vascular anatomy. These are thought to be present from birth and enlarge as the patient grows. From the therapeutic point of view, it is convenient to separate these into low-flow and high-flow malformations.

Other indications for endovascular interventional radiology in the head and neck include the pre-operative embolization of various hypervascular tumours including paragangliomas, juvenile angiofibromas, extracranial meningiomas and endolymphatic sac tumours. Uncontrolled, spontaneous epistaxis and oral or nasopharyngeal haemorrhage

secondary to malignant tumour, radiotherapy or trauma may require urgent embolization which can be life-saving. Traumatic or congenital arteriovenous fistula (AVF) of the head and neck are now usually dealt with by endovascular techniques.

IMAGING

Useful information may be obtained from ultrasound and computed tomography (CT) but magnetic resonance imaging (MRI) is the examination of choice. MRI accurately defines the extent and depth of vascular anomalies of the head and neck. It also provides information on whether the lesion appears discrete or invasive which is of fundamental importance in surgical planning. Contrast administration is helpful in defining the full extent of haemangiomas and solid, hypervascular components of vascular anomalies and tumours. Signal void within a lesion raises the possibility of high flow due to arteriovenous (AV) shunting which may be further elucidated by MR angiography.

Table 50.1 Vascular Anomalies According to Endothelial Cell Characteristics

Tumours
Juvenile haemangioma
Rapidly involuting congenital haemangioma
Non-involuting congenital haemangioma
Kaposiform haemangioendothelioma
Tufted angioma
Pyogenic granuloma
Vascular malformations
High flow
Arteriovenous malformation
Low flow
Venous malformation
Lymphatic malformation
Lymphatic-venous malformation
Capillary (or venular) malformation (portwine stain)

Source: Adapted from Mulliken JB and Glowacki J, *Plast Reconstr Surg*, 1982; 69: 412–422, revised by the International Society for the Study of Vascular Anomalies, 1996.

Calcification in a phlebolith, a characteristic of venous malformations and gas may also exhibit signal void on MRI, mimicking high flow. Phleboliths and gas are readily identified on CT and will often be visible on plain x-ray.

Doppler ultrasound, particularly colour flow, will often reveal areas of high flow not appreciated on clinical examination, but the full characterization of the angioarchitecture of high-flow lesions, however, can only reliably be made with selective and super-selective catheter, digital subtraction angiography (DSA).

In addition to general neuroradiological catheter skills, training in the various microcatheter techniques and the handling of embolic agents, is required. A thorough understanding of vascular anatomy of the head and neck is essential. There are numerous predictable anastomoses between branches of the external carotid artery (ECA) system and the intracranial circulation in addition to critical supply to the cranial nerves from certain ECA branches. A detailed account of these is beyond the scope of this text and the interested reader is referred to texts listed in the bibliography.

EQUIPMENT

High-quality, bi-plane angiography with fluoroscopy and road map facility is essential for the avoidance of inadvertent penetration of embolic material through dangerous anastomoses, particularly when one is working in the region of the skull base. The success of modern interventional techniques depends in no small measure to the advances that have occurred in microcatheter and guide wire technology. Procedures are carried out using a co-axial technique. Typically an external carotid branch is selectively catheterized with a 5F or 6F guide catheter. A 2F microcatheter is passed through the guide catheter and navigated super-selectively into the desired vessel.

Thromboembolism is the main risk of these procedures. Haemostatic valves permit continuous flushing of catheters with heparinized saline throughout the procedure in addition to systemic heparinization employing point of care assay to monitor clotting (ACT).

The list of embolic materials employed is extensive and growing (Table 50.2). It includes agents for temporary and permanent occlusion, liquid or particulate agents and

Table 50.2 Embolic Agents in Common Use

Large vessel	Medium vessel	Small vessel
Coils: Pushable	**Gelatin:** Gelfoam sponge/particles	**Particles:** PVA 50–150 µm Embospheres® Embozene®
Detachable – Electrolytic thermal mechanical etc.	**Particles:** PVA 250–1000 µm	**Liquids:** Cyanoacrylate/lipiodol
Balloons	Trisacryl gelatin microspheres (Embospheres®)	Ethylene vinyl alcohol copolymer (EVAL – Onyx®)

Abbreviation: PVA, polyvinyl alcohol.

coils, which may be pushable (non-retrievable) or detachable (retrievable) by a variety of mechanisms. These are usually made of platinum and may be bare or covered with Dacron fibres to increase thrombogenicity. A variety of sclerosant agents for the treatment of veno-lymphatic malformations are available. These are discussed in more detail in Chapter 49.

PRINCIPLES AND PROCEDURES

Neuroendovascular therapy may be curative in its own right, e.g. coiling of cerebral aneurysms, embolization of AV fistula, dural AVF/brain arteriovenous malformation (AVM) etc., but, in the head and neck, it is usually employed to reduce operative blood loss in hypervascular lesions. In some instances, conditional on the appropriate choice of embolic agent, embolization may lead to permanent devascularization of the lesion leading to necrosis, shrinkage and cure, but usually the reduction in vascularity is temporary. Embolization and surgery therefore need to be scheduled with this constraint in mind. The aim of embolization depends on the type of lesion (Table 50.3).

Although polyvinyl alcohol (PVA) is non-resorbable and is, therefore, considered a permanent agent, in practice it acts as temporary embolic agent because recanalization occurs within the thrombus generated by the particles. Gelfoam is an example of a truly resorbable, temporary agent. Cyanoacrylate glue is widely used as an embolic agent in Europe but less often in North America due to licensing issues. It is a highly effective, permanent embolic agent which, because it is a liquid, is capable of distal penetration. It polymerizes rapidly once it comes into contact with ionic solutions including blood. This process can be delayed by mixing it with lipiodol which also renders it radio-opaque. Because it is capable of penetrating small branches the risk of cranial nerve damage and inadvertent intracranial embolization is much greater than with particulate embolization.

Ethylene vinyl alcohol copolymer dissolved in dimethyl sulfoxide (DMSO) (Onyx®) is a recently introduced liquid embolic agent which has been found to be extremely useful in the treatment of AVMs of the brain and dural AVF. It is showing promise in the management peripheral AVMs including the head and neck.

Effective treatment of an AVF requires point occlusion of the fistula and proximal draining vein. This is not always as straight forward as it may seem due to problems of access and difficulties accurately identifying the exact site of the fistula. Detachable balloon occlusion of AV fistula was the earliest type of neuroendovascular procedure and it remains an effective method of treatment. Coil occlusion, however, is generally preferred because it affords a greater degree of control at the fistula site, and the risk of migration and distal embolization is reduced.

Thus, although there is commonality of the techniques and the materials employed, the aim of embolization is not the same in every case and an understanding of the natural history of the lesion, before and after treatment, is essential. For example, whilst proximal occlusion of feeding arteries is desirable in epistaxis, it is contraindicated in the treatment of AVMs, as this would lead to angiogenesis and vascular recruitment around the periphery of the lesion making subsequent, curative treatment more difficult.

In the head and neck, particularly in the facial vessels, vascular tortuosity and lack of external support often makes peripheral microcatheter vascular access difficult if not impossible. Conversely, a superficial location lends itself to direct puncture and this is, therefore, a technique that is frequently employed, not only of necessity for angiographically occult, low-flow malformations but also for peripheral high-flow AVMs.

There are some situations where free flow around a microcatheter during embolization is essential, e.g. particulate embolization of a glomus jugulare from the ascending pharyngeal artery and others where a wedged microcatheter position is desirable, e.g. onyx embolization of an AVM to achieve good nidal penetration. In the former, a wedged position risks forcing particles through anastomoses to the vertebral circulation with a consequent risk of stroke or occlusion of the supply to the vasa nervosum of the lower cranial nerves.

ARTERIOVENOUS MALFORMATIONS

The target for AVM embolization is the 'nidus' – the abnormal vessels which represent the level of the shunt. After occlusion of the nidus it is desirable to occlude the proximal draining vein. The lesion may be a discrete or diffuse collection of anomalous vessels comprising a plexiform network resulting in AV shunting or may include larger AV fistula responsible for the majority of the shunt.

Table 50.3 Choice of Embolic Agent According to Target

Condition	Target	Agent
Tumour Haemangioma	Tumour capillary bed	PVA (NBCA)
AVM	Nidus	NBCA, Onyx
AVF	Point occlusion of fistula	Coils, balloon
Epistaxis	Reduce regional arterial pressure	PVA
Veno-lymphatic malformation	Sac of abnormal vessel	Sclerosant, e.g. alcohol, ethibloc etc.; NBCA

Abbreviations: AVF, arteriovenous fistula; AVM, arteriovenous malformation; NCBA, *N*-butyl cyanoacrylate; PVA, polyvinyl alcohol.

In either case high flow, secondary to the AV shunt is a hallmark feature. Over time, this leads to arterial and venous dilatation, tortuosity and occasionally aneurysm formation.

The exception to targeted nidal embolization of an AVM is the occasional requirement for pre-operative devascularization of large feeding arteries to high-flow AVMs immediately prior to surgery. In such cases proximal embolization is acceptable. Pre-operative occlusion of surgically inaccessible arterial feeders reduces blood loss and improves visualization of the limits of the lesion making curative excision more likely and, provided surgery is carried out soon after embolization (24–48 hours), peripheral recruitment of feeders should not be a problem.

As with all vascular lesions of the head and neck close consultation between the surgeon and the interventional radiologist is essential to plan the appropriate treatment strategy. Understanding the goal of treatment is crucial. The location of the AVM, angioarchitecture of the nidus and the feasibility of vascular access, defined by angiography merely determine the most effective method of achieving that end. The appropriate choice of embolic agent, the method of access and the target follow from that.

HAEMANGIOMAS

Haemangiomas usually occur in infancy and rarely require active treatment due to the tendency for spontaneous involution. Indications for treatment include threat to vision, airway obstruction, haemorrhage or skin necrosis associated and infection. High output cardiac failure and consumptive coagulopathy (Kasabach–Merritt syndrome) may occur with large visceral haemangiomas dictating the need for intervention. Embolization may be required prior to surgery. The technique employed is similar to that for the embolization of a hypervascular tumour.

HYPERVASCULAR TUMOURS

In this group of conditions, we can include paraganglioma (glomus, chemodectoma), meningioma, juvenile angiofibroma, endolymphatic sac tumour and hypervascular metastases (typically, thyroid and renal). Detailed selective and super-selective angiography is performed to define the feeding arteries and define any dangerous anastomoses. The largest contributing branch is usually embolized first. With the microcatheter tip in the appropriate vessel, in a condition of free flow around the catheter, a suspension of PVA particles (150–300 μm) in contrast medium is injected under fluoroscopic control until near stasis is achieved. The catheter is then flushed with saline. In some instances, fibred pushable coils will be placed in the pedicle to ensure haemostasis. The procedure is then repeated in each of the feeding arteries until the tumour is devascularized or the risks of further embolization are judged to outweigh the potential benefit.

By virtue of their uniformity (size and shape) together with the smoothness of their surface, biocompatible microspheres (Embosphere®, Embozene®) are less thrombogenic than PVA. This results in better penetration of tumour microvasculature compared to the mixture of thrombus and embolic agent that more irregular particles such as PVA induce. Experience suggests that embolization with these newer embolic agents translates to more effective tumour devascularization compared to PVA.

Some tumours, particularly paragangliomas, may have AV shunts within the tumour circulation. These carry the risk of pulmonary embolization of small particles. If suspected on angiography, larger particles may be employed at the outset to occlude this component. Once this has been achieved switching to smaller particles will achieve a more effective devascularization of the intra-tumoural vessels.

ARERTERIOVENOUS FISTULA

AVF of the head and neck may arise from the branches of the ECA or the vertebral arteries (VA). The latter usually shunt into the adjacent vertebral venous plexus and may be congenital or arise secondary to trauma which can be penetrating or non-penetrating. AV fistula of the ECA may occur secondary to trauma, infection, malignant invasion or radiotherapy. They are a feature of hereditary haemorrhagic telangiectasia (Osler–Weber–Rendu syndrome).

Vertebro-vertebral fistula can usually be occluded by the endovascular route employing detachable balloons or coils. If the shunt is so large that point occlusion of the fistula is not feasible then ‘trapping’ the fistula may be necessary. This involves occlusion of the vertebral artery above and below the fistula. Occlusion from above usually requires retrograde navigation of the vertebral artery from the contra-lateral side via the vertebro-basilar junction.

AVF of the ECA may present with a pulsatile mass or haemorrhage. Occlusion with coils or a liquid embolic agent may be necessary and is usually curative.

EPISTAXIS

Spontaneous epistaxis can usually be controlled by anterior and, if necessary, posterior nasal packing. Nasal endoscopy is frequently employed to ligate the sphenopalatine artery and its branches. If, despite these measures, it cannot be controlled, embolization with PVA particles or biocompatible microspheres is usually highly effective. Super-selective catheterization of the sphenopalatine artery is performed and, under conditions of free flow, 150–300 μm particles suspended in iodinated contrast medium are injected on the side of the epistaxis. Bilateral embolization may be required to control the haemorrhage but carries an increased risk of tissue necrosis.

The technique is similar to the embolization of hypervascular tumours but the principle in this case is to reduce the arterial head of pressure to the nasal mucosa rather than

occlude the microvasculature of the nasal mucosa. This technique may also be employed in oro-pharyngeal haemorrhage uncontrolled by other methods. The distressing and life-threatening condition of nasal mucosa rather than occlude the microvasculature of the nasal mucosa. This technique may also be employed in oro-pharyngeal haemorrhage uncontrolled by other methods. The distressing and life threatening condition of 'carotid blow-out' requires more drastic therapy. This is usually due to malignant invasion of the common or internal carotid artery in the setting of an open wound, leading to massive haemorrhage. Carotid occlusion (trapping) may be life-saving but carries a significant risk of stroke even if the collateral circulation of the circle of Willis appears intact. Stenting of the carotid artery has been successfully employed in some instances avoiding the need to occlude the artery.

VENO-LYMPHATIC MALFORMATIONS

These will often be dealt with by sclerosant therapy but this may not be suitable for very large malformations. They are angiographically occult which means they cannot be accessed from the arterial route. Venous outflow is exceedingly slow and a retrograde venous approach is usually not possible either. Direct puncture and contrast venography to define the malformation and confirm an intravascular position may allow injection cyanoacrylate glue as a prelude to excision (Figures 50.1 through 50.5).

Top tips

Investigation

- Signal void on MRI – consider high-flow vascular lesion, calcification or gas.
- CT and contrast-enhanced computed tomography (CECT) will differentiate these conditions.
- DSA required to define angioarchitecture and guide endovascular treatment.

Therapy

- Pre-operative embolization can significantly reduce blood loss in hypervascular lesions.
- Embolization is the curative treatment of choice for AV fistula and certain AVMs.
- Emergency embolization may be life-saving in uncontrolled haemorrhage.

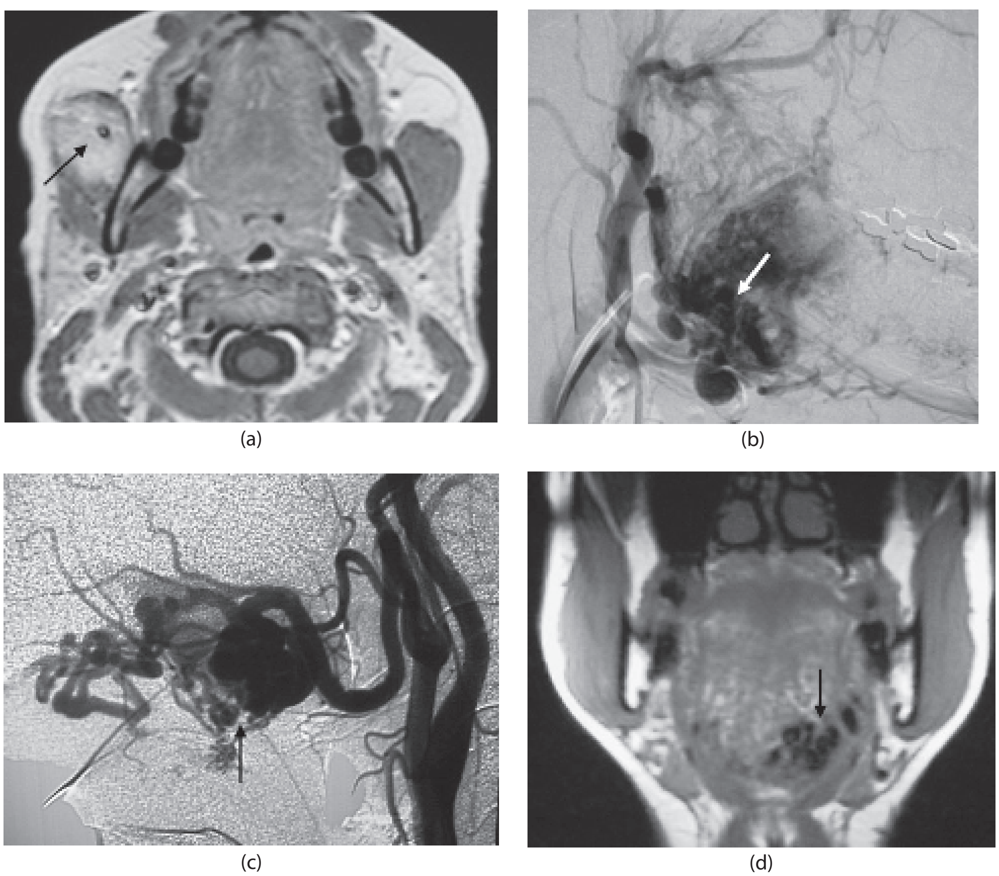


Figure 50.1 Appearance of vascular lesions of the head and neck on magnetic resonance imaging (MRI). (a) Axial contrast enhanced T1-weighted (T1W) MRI reveals a solid enhancing component and a region of flow void in a presumed haemangioma of the masseter. (b) Lateral digital subtraction angiography (DSA) shows corresponding tumour blush and enlarged facial artery. In contrast, the submental AVM in panels (c) and (d) illustrate a lesion exhibiting exclusively, flow void on coronal T1W MRI corresponding to the arteriovenous malformation (AVM) nidus revealed on lateral DSA.

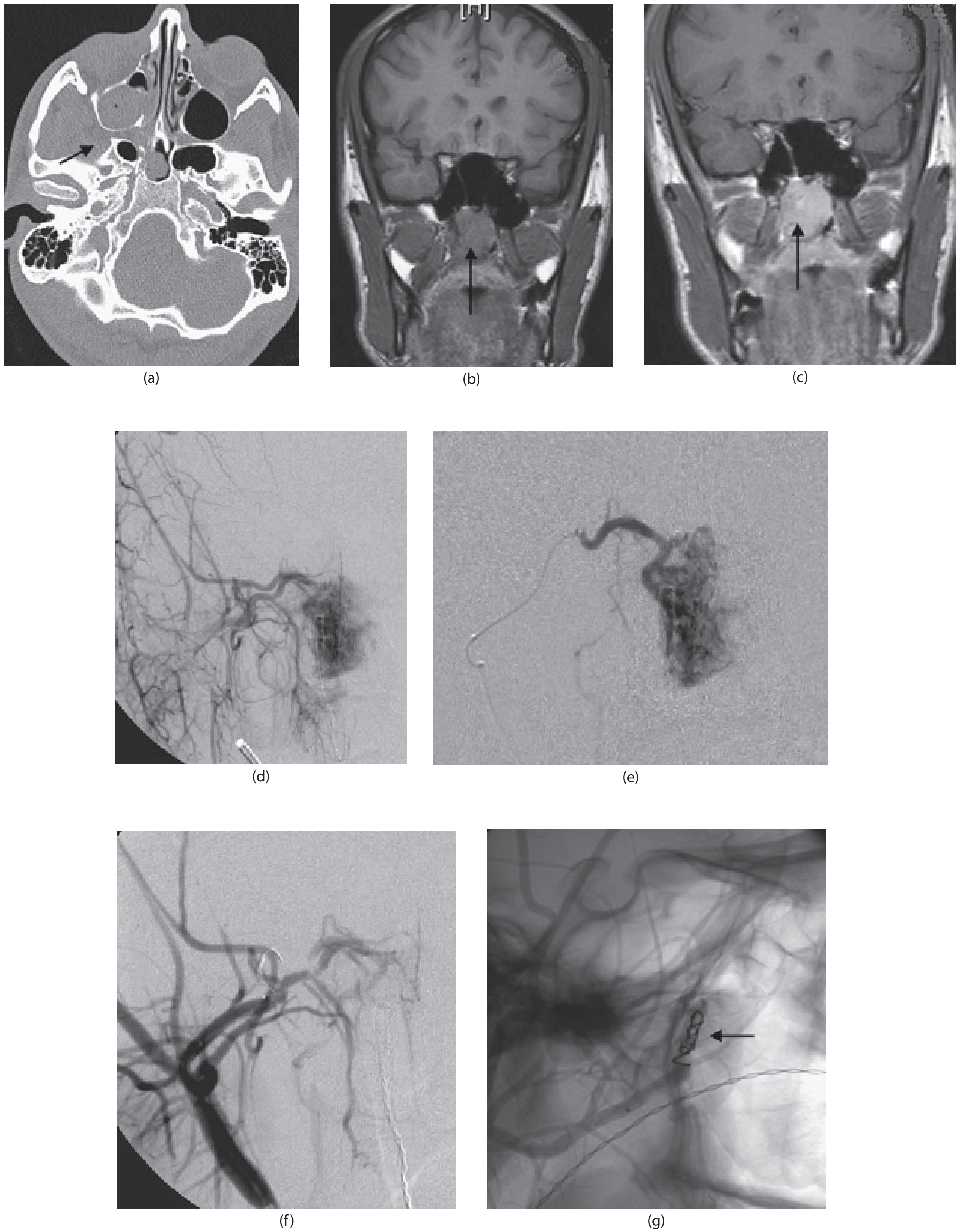
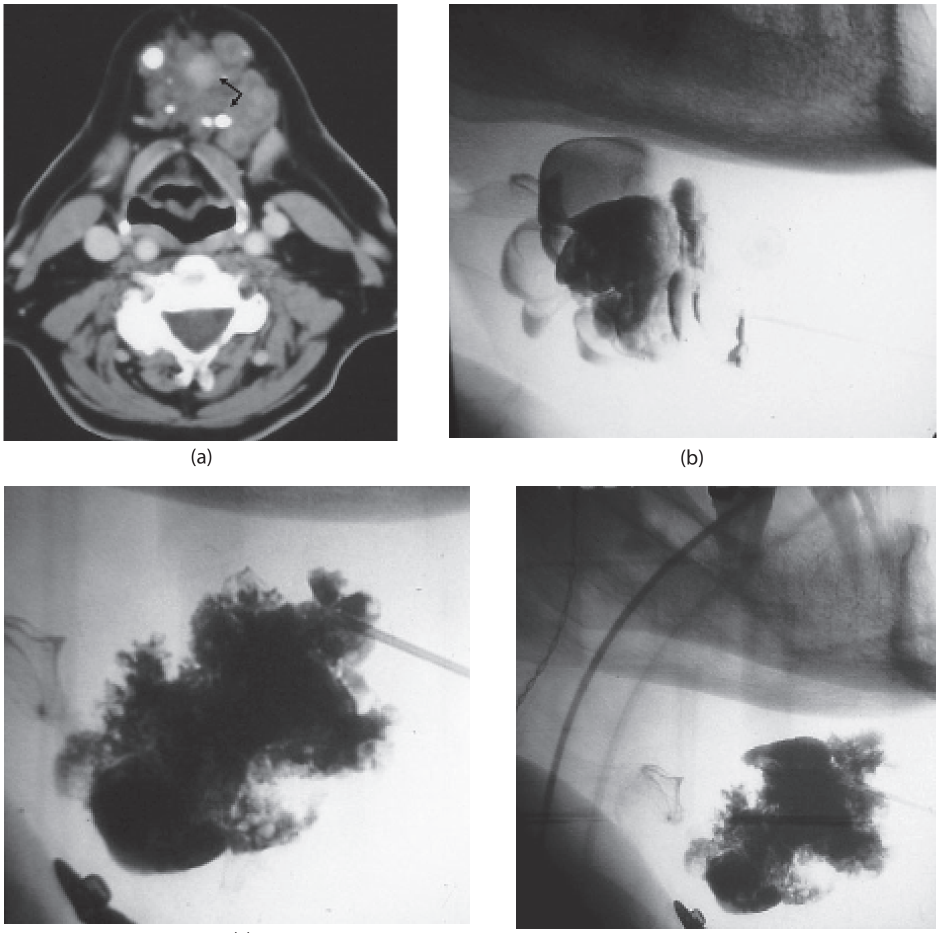
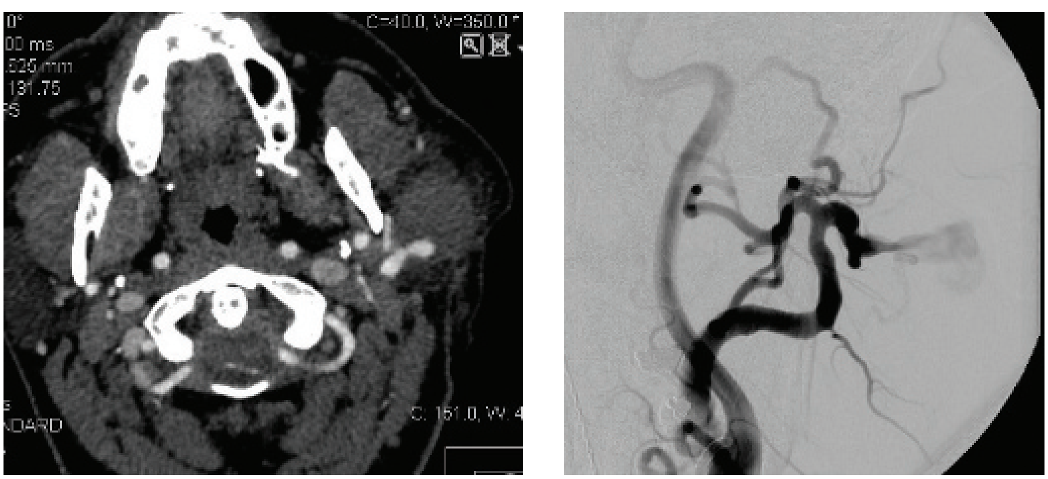


Figure 50.2 Juvenile angiofibroma. (a) Axial computed tomography (CT) reveals characteristic enlargement of pterygomaxillary fissure. (b) and (c) Coronal magnetic resonance imaging (MRI) before and after contrast delineate a brightly enhancing mass in posterior nasal space. (d) and (e) Frontal selective and super-selective DSA show typical tumour blush. (f) and (g) Pre-operative, super-selective embolization of tumour with PVA and coils. (Courtesy of Dr Adam Ditchfield, Wessex Neurological Centre.)



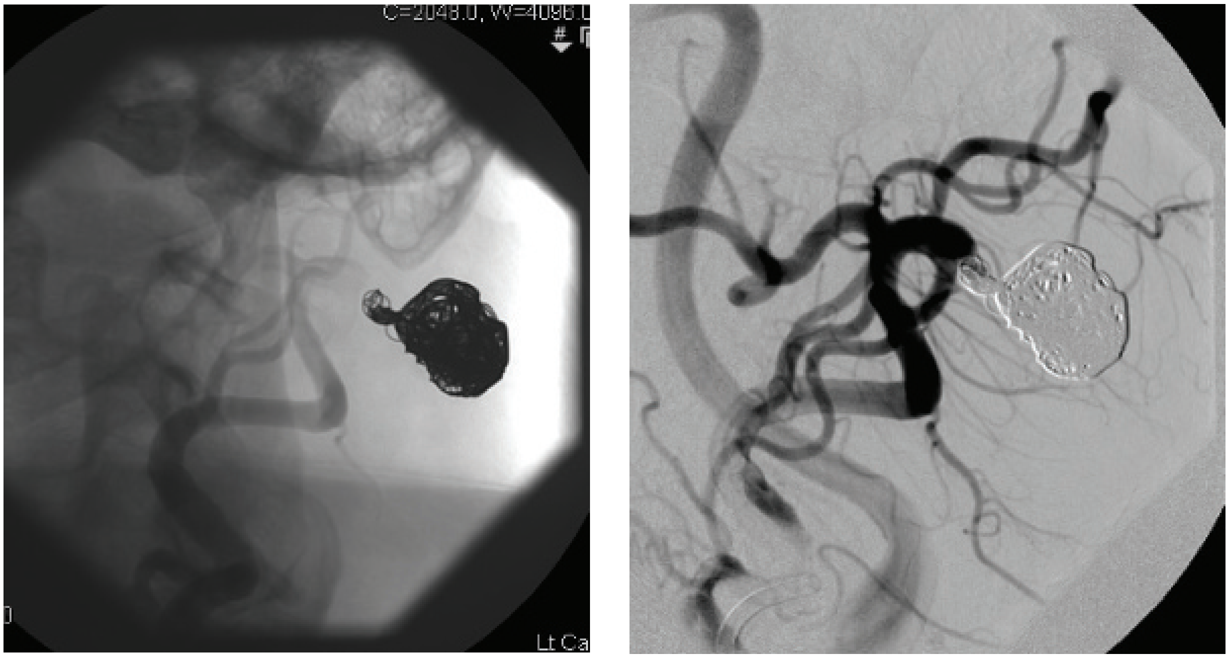
(a) (b) (c) (d)

Figure 50.3 Large sub-mental, venous malformation. (a) Axial CT reveals characteristic phleboliths and venous lakes (arrows). (b) Direct, percutaneous venography confirms slowly emptying venous lakes. (c) and (d) Pre-operative embolization with cyanoacrylate/lipiodol.



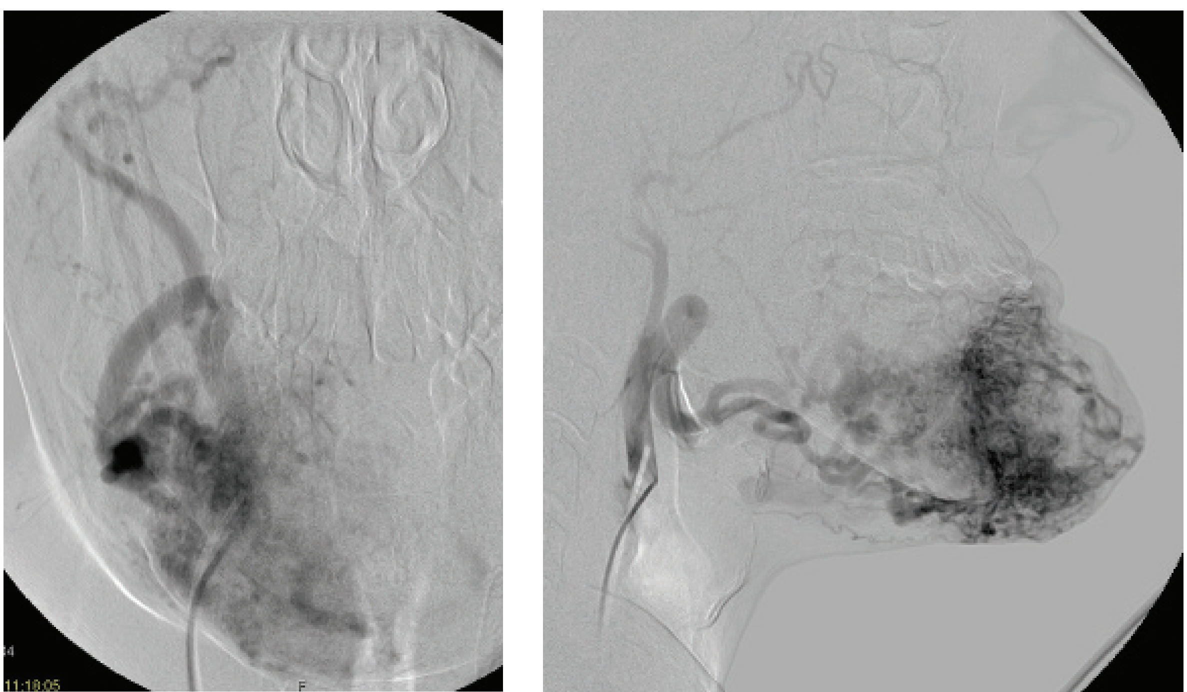
(a) (b)

Figure 50.4 Traumatic arteriovenous fistula of the left superficial temporal artery resulting from a stab wound 20 years previously. The patient presented with pain and a sudden increase in size suggestive of haemorrhage. CT angiography (a) reveals an aneurysm at the site of the fistula with a small patent lumen within a largely thrombosed aneurysm or varix. Angiography confirmed virtual occlusion of the fistula and a residual aneurysm which filled and emptied slowly (b and c). This was occluded with coils (d) to avoid spontaneous recanalisation of the aneurysm and or fistula. (*Continued*)



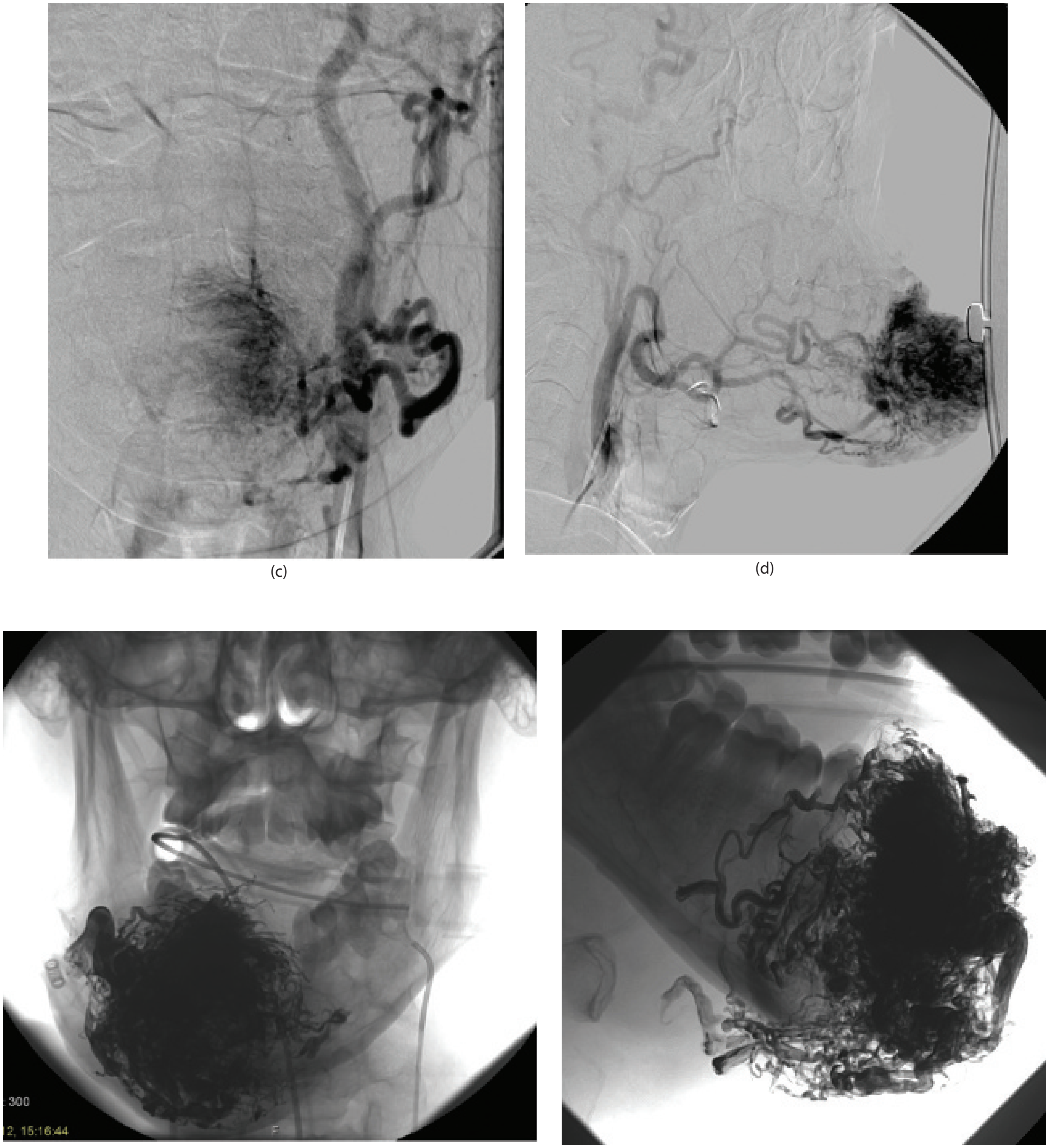
(C) (d)

Figure 50.4 (*Continued*) Traumatic arteriovenous fistula of the left superficial temporal artery resulting from a stab wound 20 years previously. The patient presented with pain and a sudden increase in size suggestive of haemorrhage. CT angiography (a) reveals an aneurysm at the site of the fistula with a small patent lumen within a largely thrombosed aneurysm or varix. Angiography confirmed virtual occlusion of the fistula and a residual aneurysm which filled and emptied slowly (b and c). This was occluded with coils (d) to avoid spontaneous recanalisation of the aneurysm and or fistula.



(a) (b)

Figure 50.5 Large mental AVM presenting with recurrent skin necrosis and haemorrhage treated by staged embolisation with Onyx prior to successful surgical excision and skin grafting. Preoperative elective angiography of the right and left facial arteries, AP and lateral (a–d) and following embolization (e and f). (*Continued*)



(c) (d) (e) (f)

Figure 50.5 (*Continued*) Large mental AVM presenting with recurrent skin necrosis and haemorrhage treated by staged embolisation with Onyx prior to successful surgical excision and skin grafting. Preoperative elective angiography of the right and left facial arteries, AP and lateral (a–d) and following embolization (e and f).

SUGGESTED READINGS

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SECTION VII

TRAUMA

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Assessment and initial management

MOHAN FRANCIS PATEL

CONTENTS

The facial soft tissues and underlying facial bony skeleton are, at once, the most important and most vulnerable portion of the human body. Here the personality is perceived and the senses reside but it is also here that accident and assault most frequently occur.

Some compensation for this is found in the ready access of the area for examination, and the obvious familiarity of the structures. The facial skeleton is also largely subcutaneous and readily amenable to direct and indirect repair.

The initial temptation to allow spectacular and disfiguring facial injuries to override measured surgical practice must be resisted.

The proactive and comprehensive systems taught on all advanced trauma life support (ATLS) and trauma skills courses are followed with prompt, appropriate and structured assessment and action with constant reappraisal of the patient's condition.

GENERAL ASSESSMENT

The care of the trauma patient arriving in an accident and emergency department (A&E) unit can be broken down into four elements:

1. A primary survey is carried out, in which the so-called ABCs are assessed and if necessary dealt with immediately.
   - *A (airway):* The oronasal airway is assessed, foreign bodies cleared, blood and inspissated secretions aspirated: a check is made that a potentially unstable cervical spine fracture is not displaced.
   - *B (breathing):* This is checked to ensure that the apparently clear airway is functioning. At this stage, assisted respiration and ventilation with necessary intubation or tracheal access surgery may be required.
   - *C (circulation):* The presence of an adequate blood circulation is assessed and any significant haemorrhage is controlled, usually by pressure.
2. The second element is resuscitation of the patient and includes the constant reassessment of problems identified in the primary survey, with continuation of care. Treatment of shock is commenced, including the placement of vascular lines, urinary catheters and nasogastric tubes if appropriate, and electrocardiogram (ECG) monitoring. In the case of multi-system trauma, emergency screening radiography is carried out to include lateral cervical spine, chest and pelvic x-rays.

3. The third element of the trauma patient's care is a consolidation exercise where a thorough total examination of the patient is carried out as a 'secondary survey'.
4. In the fourth element, definitive care will be decided by specialist teams, and it may be necessary to transfer the patient for this (for example to a maxillofacial or neurosurgical unit). The primary surgery is usually carried out by the frontline team in the A&E department, whilst maxillofacial surgeons will require to undertake a secondary survey prior to the definitive management of maxillofacial injuries.

After the initial care of the trauma and before the patient is passed to specialist maxillofacial assessment and initial management, it is worth considering a number of topics in more detail.

CERVICAL SPINE INJURIES

It should be assumed that any significant maxillofacial injury may be associated with a cervical spine injury. Care, therefore, must be taken when the head and neck are manipulated during maintenance of the airway, examination and radiology. A lateral view of the cervical spine showing all cervical vertebrae must be examined and if there is a high index of suspicion, then, cervical anterioposterior and open mouth odontoid views should also be taken. Confirmation of a cervical spine injury may require simple tomography or computed tomography (CT) scanning. Where there is doubt the opinion of a neurosurgeon should be sought, and the use of a semi-rigid cervical collar considered in the interim.

SKULL FRACTURES

Although these fractures are not invariably involved with brain injury, they provide a significant index of suspicion with regard to present or future neurological deficit or the presence of developing haematomas.

Skull vault fractures may be linear when they will often require no direct treatment, or depressed, when they may require elevation. Basal fractures are often diagnosed by a leakage of cerebrospinal fluid (CSF), a classic bruising in the mastoid area (Battle's sign) or blood sequestered behind the tympanic membrane. Skull fractures which expose the brain or dura require early surgery. Patients with head injuries require continuous assessment and reassessment of their neurological status and this monitoring may be done by the use of a combination of the Glasgow Coma Scale (GCS), pupillary assessment and extremity weakness. Abnormal and particularly deteriorating results of these assessments should raise suspicion of neurological damage or of a developing space-occupying lesion.

Glasgow coma scale

This system of assessment works on the basis of numbers being allocated to a spectrum of grades of neurological responses, including eye opening, best motor response and best verbal response. The scores for the three groups are summated as the GCS. When these assessments are repeated, a trend towards improvement or deterioration can clearly be seen and appropriate action should be taken.

- Eye opening is graded 1–4 as follows:
  1 = no eye opening
  2 = opening to pain
  3 = opening to speech
  4 = spontaneous opening
- The best motor response is graded on limb movements from 1 to 6:
  1 = no movement
  2 = extensor response only
  3 = abnormal flexion
  4 = withdrawal from painful stimuli
  5 = movement towards painful stimuli
  6 = movement of limb on command
- Capability of verbal response is graded from 1 to 5:
  1 = no verbal response
  2 = inarticulate sound
  3 = recognizable words inappropriately uttered
  4 = confused conversation
  5 = fully orientated

Patients with GCS <8 are in a coma and have a severe head injury. Those with a GCS of 9–12 are considered to have a moderate head injury and a GCS of 13–15 indicates a minor head injury.

Pupillary assessment

Pupil size is measured regularly. A unilaterally enlarged pupil may indicate a contralateral space-occupying lesion. It is helpful to know from relatives or friends if the patient had a disparate pupil size prior to the trauma. Slow light reactions may indicate brain injury.

Extremity weakness

Equal movement of limbs on both sides is looked for whilst a lateralizing weakness suggests contralateral brain injury.

The use of GCS, pupillary assessment and extremity weakness assessment together provides a sensitive and easily understood neurological monitoring system.

OCULAR INJURY

The proximity of swelling, bruising, lacerations and facial fractures around the orbits and the type of trauma suffered

will give some indication as to the likelihood of eye injury. If there is any doubt, an ophthalmologist must be asked to see the patient and guidance sought as to whether exploration of the orbit surgically might be required.

The eyelids, conjunctiva, cornea and globe should be grossly examined for damage, and particularly for lacerations. Visual fields in both eyes should be grossly measured, with the patient wearing glasses where appropriate, either counting fingers at a distance or reading newspaper print. The pupils are assessed for normal shape and light response. The eye should be examined with an ophthalmoscope for internal derangement. Flaccidity of the globe on palpitation may indicate a laceration.

PREGNANCY

There will be some obvious differences in assessing the pregnant woman. Where x-rays are essential they should be taken and an obstetrician requested to see the patient as soon as possible.

TRAUMATIZED CHILDREN

It is often difficult to examine a traumatized and distressed child accurately and a history may be impossible to obtain. In view of the child's small size and incompletely calcified skeleton, there is often a higher chance of organ damage, whilst paradoxically the skeleton is more often spared than in adults. A thorough examination and the advice of a paediatrician is, therefore, essential; in most hospitals, a paediatric team will wish to become closely involved with the child's management. It should be remembered that in view of a child's relatively large surface area in proportion to body volume, loss of heat may occur more rapidly than with an adult, and the smaller blood volume can result in a child becoming shocked with what appears to be a relatively small blood loss in adult terms. It should be remembered that a distressed and terrified child can be severely traumatized psychologically, as well as physically, and sympathetic management should reflect this concern.

ABDOMINAL TRAUMA

It can be easy for occult abdominal damage to remain so until the patient descends into extremis or death, and it is therefore important that the abdomen is examined thoroughly and then reassessed. A history of trauma to, or pain from, the abdomen should be noted and the abdomen inspected for wounds and contusions. A careful auscultation should be carried out to assess the presence of bowel sounds which may be absent as in an ileus owing to peritoneal irritation by blood or bowel contents, or extra-abdominal injury to the spine. Gentle palpation will elicit pain, and involuntary muscle guarding is a sign of underlying peritoneal irritation. A routine rectal examination may show blood from a bowel perforation or more local damage.

LARYNGOTRACHEAL DISRUPTION

Fractures of the larynx are uncommon and are indicated by emphysema, hoarseness and local crepitus. Loud tracheal breath sounds may indicate partial obstruction of the airway that may be followed by a complete cessation of sounds when total obstruction occurs. Use of endoscopy to assess tracheal damage is often invaluable.

Obstruction in the trachea and upper airway can be overcome with a number of surgical interventions depending on the severity of the obstruction and its level. A needle cricothyroidotomy with jet insufflation of oxygen (Figure 51.1) can be a useful emergency measure and allows for formal tracheostomy to be carried out in a less hurried fashion.

Apart from respiratory obstruction, tracheostomy may be indicated in patients where there are flail segments or lung contusion or in severe head injury cases. This procedure, which can be carried out under either local or general anaesthesia, should be in the armamentarium of all surgeons. The technique is fundamentally a simple one. However, for most surgeons who do not perform it regularly, the procedure can be more testing than textbooks suggest. A conscious patient is likely to be distressed and the neck can after trauma, be engorged with oedema fluid and blood. Bearing this in mind if a methodical approach is taken, the procedure is usually accomplished successfully.

MAXILLOFACIAL ASSESSMENT AND INITIAL MANAGEMENT

Maxillofacial injuries often excite considerable anxiety amongst clinical and nursing members of the trauma team, due to the grotesque swelling and bruising with

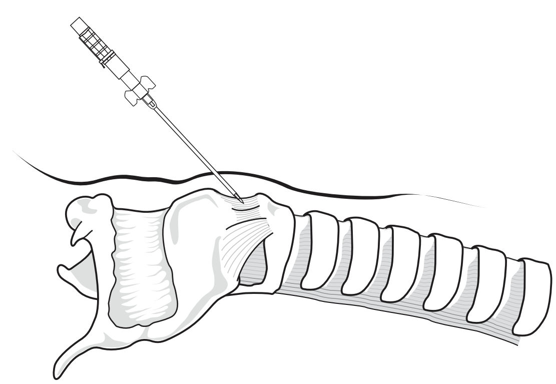


Figure 51.1 Jet insufflation of oxygen via a needle cricothroidotomy.

which they are associated. The majority of road trauma and interpersonal violence cases are associated with maxillofacial head injuries to a greater or lesser extent and it is important therefore that these injuries are treated practically and without mystique.

The very real risk to both the nasal and oral airway in severe injuries gives additional concern, and the temptation to employ the aphorism that 'the injury invariably looks worse than it is', should be resisted. Although this is often the case, a careful check using the fundamental 'ABC' system can prove life-saving.

Fractures of the facial bones are often difficult for other clinicians to understand, owing to the close juxtaposition of intricate bony complexes and the need to comprehend these in three dimensions. In addition, the difficulty of obtaining good quality diagnostic radiographs, particularly late at night, of a swollen patient in pain, and often without a specialist radiographer, can make diagnosis yet more fraught.

We have discussed the importance of first identifying collateral injuries before concentrating on the maxillofacial region. However, once potentially life-threatening injuries have been identified and controlled, maxillofacial injuries must be accurately assessed. These may be broadly divided into lacerations of the soft tissues of the scalp, face and neck, and fractures of the facial skeleton. It should be remembered that there is often a direct relationship between an overlying laceration and an underlying fracture.

LACERATIONS OF SOFT TISSUE

These wounds cause a discontinuity in the soft tissue at any level, from superficial skin abrasions to deep cuts, and may open up a number of tissue planes. They may be clean, contused or puncture wounds, or any combination of these three.

Initially, any significant haemorrhage should be controlled with pressure. The presence of foreign bodies or the involvement of important underlying structures and any loss of tissue can then be assessed. The possibility of infection must not be overlooked, and although clean non-contused wounds may not require antibiotics, old or dirty wounds or those occurring in a medically compromised patient, such as a diabetic, should be 'covered' by antibiotic prophylaxis.

Contused, deep or puncture wounds, especially those occurring out-of-doors, or as part of a multiplicity of injuries, require an assessment of the patient's tetanus immunization status. The use of tetanus immune globulin (TIG) rarely causes adverse reactions and may be considered for individual patients. If the patient has received two or more injections of toxoid in the past, TIG is only indicated if the wound is tetanus-prone or over 24 hours old. The use of equine tetanus antitoxin is potentially hazardous.

Repair of lacerations

Uncomplicated lacerations in cooperative adults and older children are usually treated well and promptly under local analgesia. The use of general anaesthesia may be necessary for complex lacerations, particularly where there is skin loss, or simple lacerations in young un-cooperative children.

The wound should first be carefully examined to enable the removal of foreign bodies (soft-tissue radiographs may help to locate radio-opaque material). Tissue with poor viability may require clean excision, but a most conservative approach must be taken in the facial region, where every effort should be made to conserve soft tissue.

Dirt should be thoroughly removed from wounds to prevent skin tattooing and a sterile nail brush should be used with dilute Savlon solution to thoroughly remove any such debris, followed by copious irrigation with sterile normal saline.

Haemostasis should be obtained by electrocoagulation for small-vessel bleeds and ties used for bleeds from larger vessels.

The cleansed wound is first loosely assembled, in order that an assessment of any tissue loss can be made. If the wound can be brought together with only moderate tension after wide undermining of the adjacent tissue if necessary, then primary closure should be carried out. If an aesthetic and functional primary closure is not possible, consideration of grafting procedures or flap development should be considered, and this is likely to be scheduled as a further elective procedure. This may involve the use of split or full-thickness skin grafts, local rotation flaps, distant pedicled flaps or free flaps with microvascular anastomosis. In these instances, temporary closure of a wound will reduce the possibility of infection or haemorrhage whilst arrangements for definitive treatment are made.

When dealing with lacerations in the facial region, it is essential to assess the integrity of the facial nerve particularly where damage to the parotid gland has occurred. The nerve ends may either be repaired immediately or tagged (with a suture) for future repair, including grafting, where nerve division has occurred.

Lacerations in the cheek may also damage the parotid duct requiring repair over a fine catheter.

Injuries to the eyelids must be associated with careful examination to rule out damage to the globe and lacrimal duct injuries.

MAXILLOFACIAL FRACTURES

The facial skeleton is arbitrarily divide into the upper third or frontal bone, middle third or bony skeleton, from the frontal bone down to the upper alveolus, and the lower third or mandible.

Upper third fractures are usually linear cracks or bony depressions over the frontal sinuses. Middle third fractures result in detachment of this portion of the facial skeleton to a greater or lesser extent from the rest through the areas of anatomical weakness identified by Le Fort during his cadaver studies, and which are illustrated in Figure 51.2.

Severe displacement of the middle third of the facial skeleton can result in the detached portion being thrust backwards down the inclined slope of the base of the skull, causing the classic 'dished-in' facies. There is also a danger that this posterior movement of the mid-facial skeleton might close off the nasopharyngeal airway. This should be assessed promptly in the primary survey of the trauma patient, and can be rectified either by attempting to draw the posteriorly impacted bony complex forward by finger pressure around the hard palate and tuberosities, or, by prompt tracheostomy.

Fractures of the middle third of the facial skeleton should be considered as a combination of the major lamella displacements described by Le Fort, and of damage to the specialized bony complexes which we recognize as the dentoalveolar, mid-maxillary, malar, nasal and orbital complexes. Fractures at more than one Le Fort level or at different levels on separate sides are common. Specialized complexes may be damaged in isolation or in any combination.

Mandibular fractures are notated by site, as condylar, ramus, angle, body or parasymphyseal fractures. The combination of parasymphyseal and angle fracture occurs most commonly, and it is wise always to look for more than one mandibular fracture.

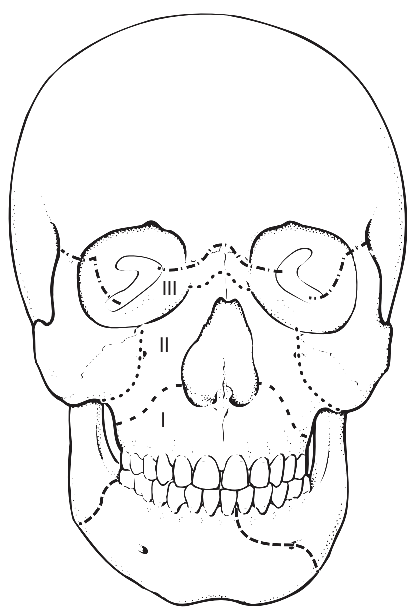


Figure 51.2 Le Fort low (I), middle (II) and high (III) fracture lines. The mandible exhibits right angle and left parasymphyseal fracture lines.

Fractures of the maxilla and mandible occur in numerous combinations, often with comminution and, whilst rarely compound in the maxilla, are invariably so in the mandible, along the roots of the teeth into the mouth.

Assessment

A clinical assessment for fractures of the facial skeleton is usually best carried out systematically from above downwards, starting with a careful examination and palpation of the cranium, gently probing through any lacerations where present for underlying bony damage.

Next, the orbital rims are examined with the nasal skeleton, malar bodies and zygomatic arches. Tenderness and step deformities or swellings will usually betray underlying fractures.

When the facial skeleton from the front has been viewed, a further examination should be made by the physician standing behind the seated patient: looking down on the facial skeleton from above can be revealing. Nasal deviation or depression and flattening over the malar prominences can be seen, as can 'thumb print' depressions over the zygomatic arch. It is always wise to question the patient with regard to previous nasal fractures that can otherwise be deceptive.

The dentition and alveolus must be carefully checked for fractured or missing teeth and radiographs of lacerated soft tissue or chest and abdominal films used to reveal the presence of avulsed teeth or dental prostheses.

The mandible is carefully examined by palpation, feeling for step defects; intra-orally, the occlusion is examined for discontinuity. The patient will be able to perceive any small disruption in the occlusion accurately. The presence of lacerations or ecchymosis in the buccal or lingual sulcae often indicates underlying mandibular fractures.

Le Fort fractures

The appearance of bilateral orbital ecchymosis and oedema of the soft tissues of the face, with disruption of the nasal skeleton, and the presence of blood in the nostrils is quite characteristic of this type of pan-mid-face fracture (Figure 51.3). The maxilla is often mobile and a CSF rhinorrhoea or otorrhoea should be looked for. If the 'examining' hand grasps the upper alveolus and gently but firmly moves it, whilst the 'watching' hand palpates at Le Fort I, II and III levels in turn, some idea of the extent of the mid-face injuries can be ascertained.

Malar complex

These fractures (Figure 51.4) are characterized clinically by a flattening over the malar prominence or zygomatic arch that can be obscured by oedema, and a difficulty

Figure 51.3 Classic appearance of panfacial fractures (at all Le Fort levels).

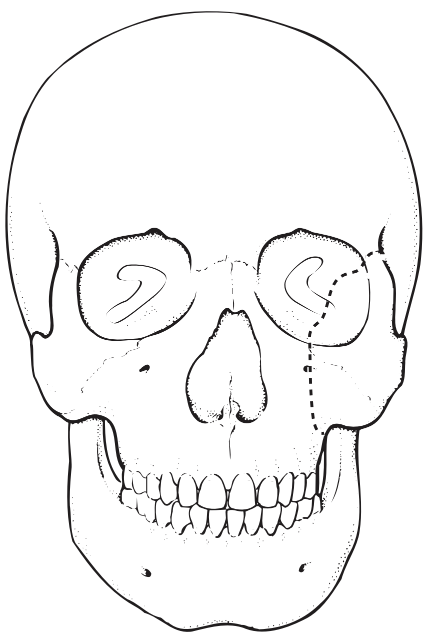


Figure 51.4 Malar complex fracture.

in moving the jaw when the coronoid process impinges on a depressed zygomatic arch. Circumorbital and subconjunctival ecchymosis may be present, with limitation of eye movements where there has been muscle trapping, often the inferior rectus in fractures of the floor of the orbit. A step defect is usually palpable in the inferior rim of the orbit and there is frequently numbness over the distribution of the inferior orbital nerve ipsilaterally.

There may be diplopia, often owing to oedema or displacement of the orbital complex, but sometimes owing to detachment of suspensory ligaments of the globe. The globe should be examined by an ophthalmologist to rule out internal derangement. Malar complex fractures and those of the orbit are frequently associated with subconjunctival ecchymosis, which has no posterior margin extending as it does from the depths of the orbit posteriorly. Punctate subconjunctival ecchymosis occurs when a blow to the eye causes the extravasation of blood below the conjunctiva related locally to the blow.

Fractures of the orbital walls

The paper-thin bones of the floor of the orbit also form the roof of the antrum and are in continuity with the zygomatic complex. Fractures to the fragile floor of the orbit also occur in isolation, particularly when there is direct blunt trauma to the globe itself which, by displacement or distortion of the globe, 'blows out' the vulnerable bone of the orbital floor. On these occasions, a herniation of peri-orbital fat and the inferior rectus muscle may occur, often with a restriction of eye movement, particularly on upward gaze (Figure 51.5), and a lowering of pupillary height on the affected side. Enophthalmos can present either early or late. The thin medial wall of the orbit is also prone to being 'blown in', with a commensurate increase in orbital volume and a danger of late enophthalmos.

Nasal skeletal fractures

Bilateral circumorbital ecchymosis is pathognomonic of this type of fracture, along with a deviation of the nose laterally where lateral force has been applied, or resulting

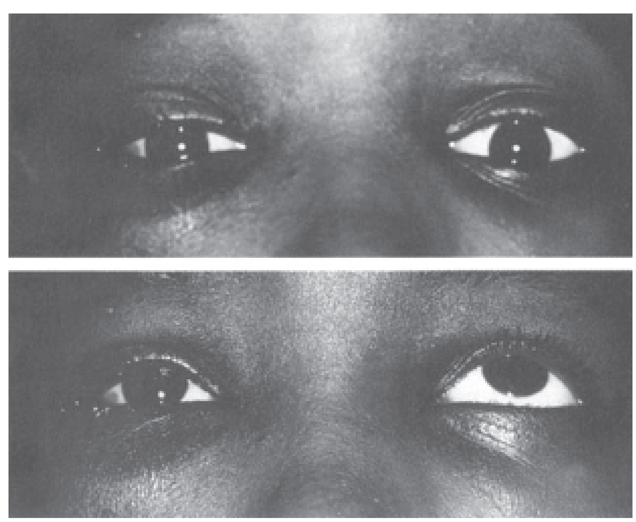


Figure 51.5 Tethering of inferior rectus muscle on upward gaze after orbital floor 'blow-out' fracture.

in the collapse of the nose where the trauma has occurred anteriorly. Epistaxis occurs invariably. In nasoethmoidal disjunction, the damage must be analysed carefully in order to plan satisfactory reconstruction. In addition, damage involving the cribriform plate may be signalled by CSF leak, and can result in anosmia.

Fractures of the mandible

These fractures are normally easy to elicit, particularly in the dentate patient. There is an inability to close the teeth into normal occlusion, with commensurate discomfort over the fracture site. Often and particularly when there has been distraction at the fracture site, there can be anaesthesia of the lower lip on the affected side, from inferior alveolar neuropraxia. Where fractures of the body of the mandible have occurred, this can often be identified by bleeding from tears in the overlying mucosa. Step defects in the occlusion and lower border of the mandible are usually easily identified.

Radiology

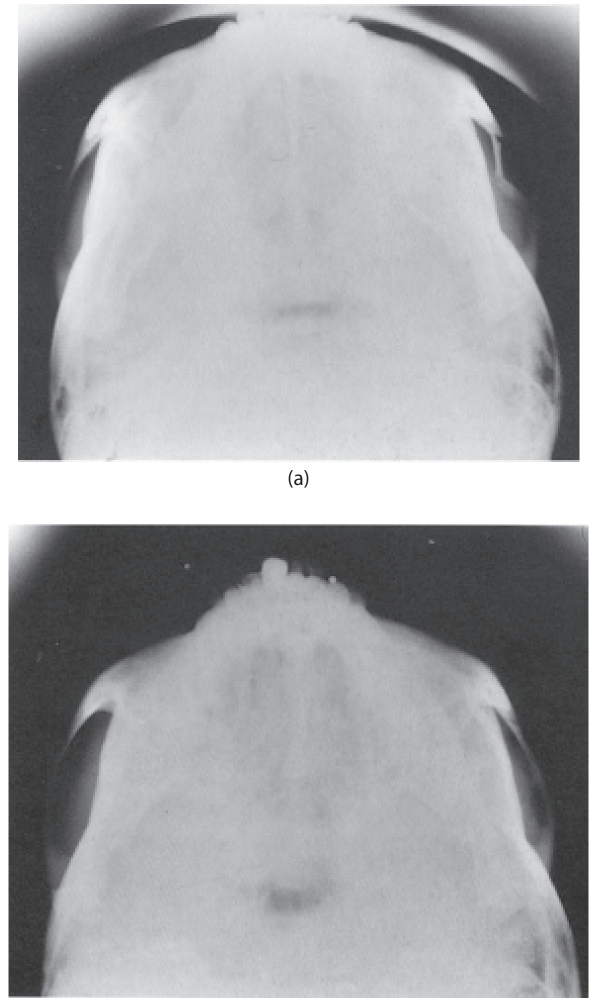
This screen of radiographs should provide adequate views for an initial diagnosis to be made:

- Submentovertical
- Occipitomental
- Lateral skull
- Orthopantomogram of mandible; or if not available the following mandibular views used in isolation or combination
- Posterioanterior view
- Lateral oblique views
- Reverse Townes view

As we have noted earlier, the possibility of cervical spine injury must first be excluded by clinical examination and, if appropriate, cervical spine views.

The submentovertical view provides a 'skyline' view of the zygomatic arches (Figure 51.6) showing the arches and any displacement. The occipitomental views show the integrity of the orbital rim and floor, providing further useful views of the zygomatic arches and will clarify the outline of the antral walls and the presence of fluid levels in the sinuses. The so-called 'hanging-drop' sign caused by soft-tissue herniating through the floor of the orbit into the antrum below is best seen in this view (Figure 51.7).

Fractures of the nasal bones and posterior maxilla can be seen on the lateral skull view. If nasal bone fractures are suspected, a 'soft-tissue' lateral will often show these clearly. The orthopantomogram allows fractures of the basal bones of the mandible, the teeth and alveolus to be assessed (Figure 51.8). As this latter view is tomographic, remember that there is always a danger of information outside the 'focal trough' not being reproduced.



(a)

(b)

Figure 51.6 Submentovertical view clearly showing (a) the pre-operative crumpled and (b) post-operative reduced left zygomatic arch as 'sky-line views'.

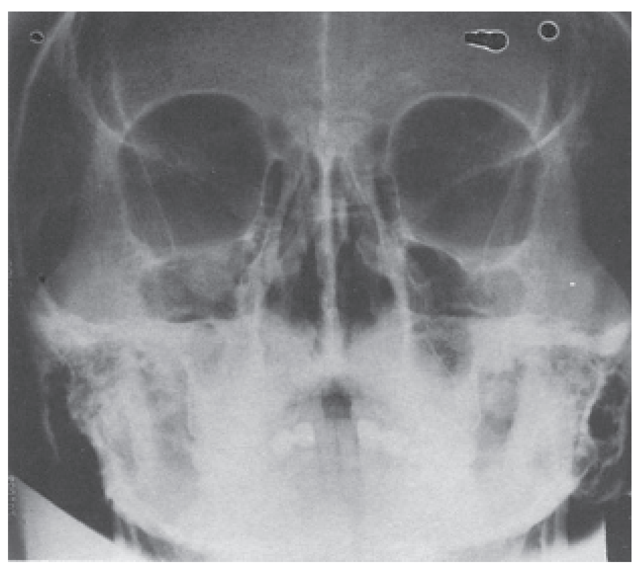
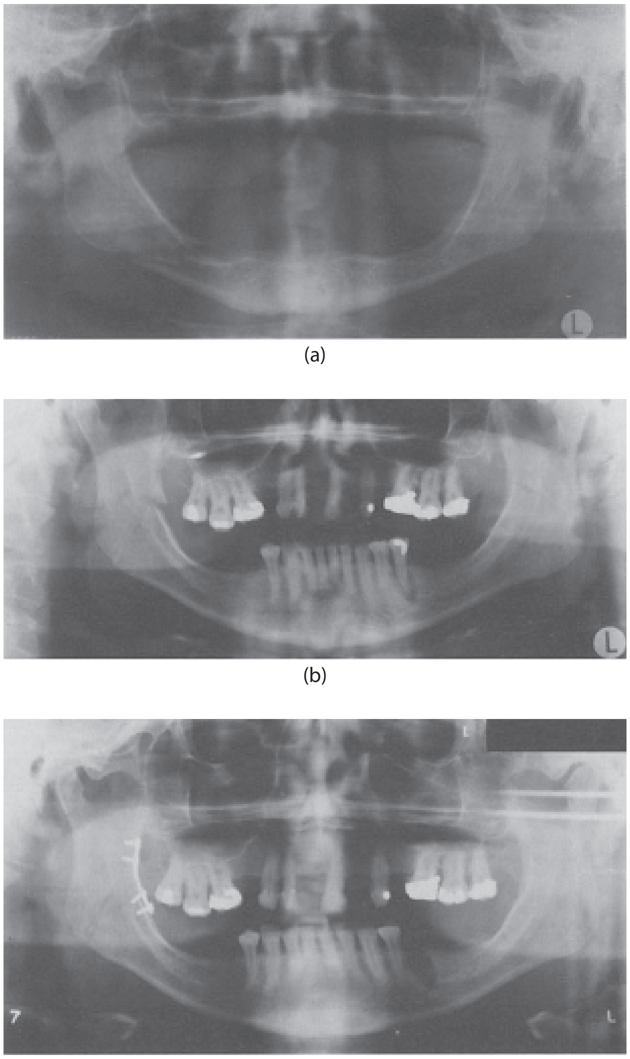


Figure 51.7 Herniation of fat through fractured right orbital floor, giving the classic 'hanging drop' sign.



(a)

(b)

(c)

Figure 51.8 Orthopantomogram illustrating (a) right body fracture in edentulous mandible, (b) right-angle fracture in partially dentate patient, (c) reduction and fixation of fracture in (b) using miniplate osteosynthesis.

The plain films here are important for the diagnosis and localization of fractures of the facial skeleton. In order to examine the three-dimensional (3D) relationships of the complex facial fractures, CT scans are invaluable, especially with 3D re-formatting. In the case of a fracture of the frontal bone over the frontal sinus, for example, a CT scan will show the extent and severity of the injury to the outer bony table and, in addition, define any involvement of the inner table of the sinus wall (Figure 51.9).

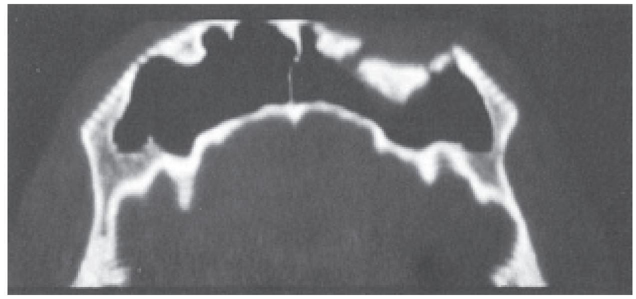


Figure 51.9 Axial computed tomography (CT) scan showing comminution of anterior wall frontal sinus with intact posterior wall.

The increasing use of CT scanning with 3D re-formatting, especially with spiral machines, is providing unparalleled imaging of complex fractures of the facial skeleton with the facility for 'virtual' surgery and with the possibility of utilising the software to mill prostheses to replace large portions of lost bone.

Top tips

- Remember! Facial lacerations may overlie an underlying fracture.
- Obtaining pre-trauma photographs builds empathy with relatives and can act as a useful operating guide.
- Sudden deterioration of an otherwise stable patient prompts reassessment of primary survey.
- Even severe lacerations are rarely associated with significant tissue loss.
- Check for damage to the lacrimal and parotid ducts and facial nerve branches before closing deep lacerations.

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52

Contemporary maxillofacial fixation techniques

DOMENICK P COLETTI

CONTENTS

INTRODUCTION

Hippocrates was the first to emphasize the importance of reduction and immobilization of the mandible fracture, with the use of the interdental 'bridal wire'. As time passed, closed reduction and stabilization with maxillomandibular fixation (MMF) was introduced by techniques such as external bandages (i.e. the Barton bandage), internal splints (i.e. Gunning splints), external frame and pin fixation and various forms of interdental wiring. These techniques rely on secondary bone healing, but have limited application in modern practice, because of the delayed return of function and higher rates of infection, malunion, non-union and malocclusion. This led to the development of open reduction and internal fixation techniques, which provides anatomical reduction and stabilization, in turn optimizing primary bone healing.

One of the earlier forms of internal fixation was the use of transosseous wires, a semi-rigid form of fixation which was an effective technique for its time, and is occasionally still employed. In the 1960s and 1970s, this technique was replaced with the advent of plates and screws. These early plating techniques were first adopted from orthopaedic experience with the treatment of long bone fractures. However, large compression plates which used bicortical screws that were placed along the inferior border of the mandible splayed the superior aspect of the fracture. Compression plates apply force to areas of the mandible which are already under biomechanical compression. Eccentric dynamic compression plates were then developed to attempt to counteract these distraction forces, but were too cumbersome and technique sensitive.

More recent advancements in plating techniques have provided many different forms of plating technology to the surgeon including non-locking plates, threaded locking plates, tapered locking plates, bicortical and monocortical fixation and rigid and semi-rigid plates. In order to achieve a level of excellence for each patient, today's surgeon must not only understand each type of technique, but also appreciate the advantages and disadvantages of each, as well as their basic principles of management. The goals of treatment should be as follows:

- Anatomic reduction and stabilization of fractures
- Preservation of facial dimensions
- Establish and preserve the occlusion
- Early return to function
- Avoidance of infection

Understanding these goals is paramount and the surgeon must weigh the risks against the benefits of the proposed management. The objective of this chapter is to provide the clinician with an overview of the advancements made in maxillofacial fixation and the types of techniques available.

CLOSED TREATMENT FIXATION

Arch bars

MMF is a hallmark principle of maxillofacial trauma which uses the patient's occlusion to establish the proper reduction and stabilization of facial fractures, thus providing a foundation to reconstruct facial form and function. Various forms of MMF have been described in the literature, e.g. eyelet loops, skeletal suspension wires and Erich arch bars. Arch bars are currently the workhorse for MMF, they are applied using circumdental wires (Figure 52.1).

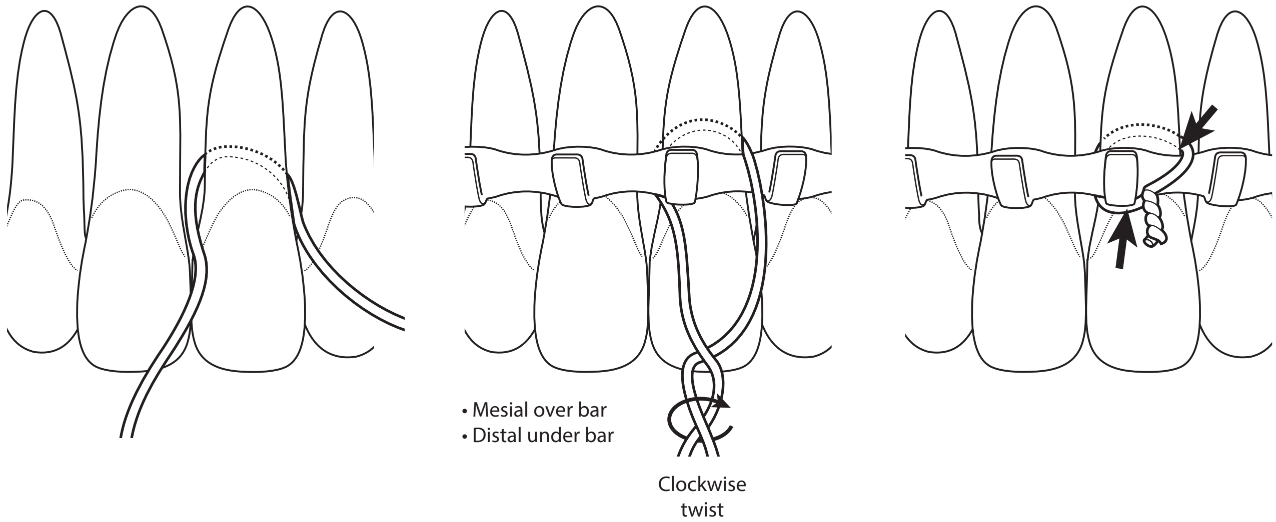

Figure 52.1 Arch bars.

The patient is placed into his premorbid occlusion upon the final tightening of the intra- and interarch wires. Arch bars are valuable in re-establishing the intra-arch contour when managing dentoalveolar fractures and they also serve as a 'tension band' by resisting the forces along the alveolar level of the mandible. They provide a versatile means of directing vectors of forces with a V–W pattern of crossbracing, to assist in fracture reduction and re-establishment of the premorbid occlusion. While arch bars provide an effective means of MMF, their use is not without consequence.

Increased surgical time both in placement and removal, risk of penetrating injury to the surgeon associated with the use of stainless steel wires, trauma to the periodontal soft tissue and compromised oral hygiene are all shortcomings of traditional arch bars. Also, arch bar placement in the paediatric patient can be difficult, depending on the patient's age and stage of tooth eruption. The height of contour position and contacts in the primary dentition may prevent the application of circumdental wires. Second, there is the potential for extrusion of the primary tooth upon tightening the wire, especially in the root resorption stage for exfoliation.

Intermaxillary fixation screws

Recently, the introduction of self-drilling/tapping intermaxillary fixation screws (IMFs) has eliminated some of the problems associated with arch bars (Figure 52.2). Many clinicians elect to use them based on a decreased risk of penetrating injury for the user, ease of placement with shorter operating room time, decreased trauma to the periodontium, convenience of maintaining oral hygiene, and the ability to use them both intraoperatively and postoperatively, such as with guiding elastics. The first generations of IMF screws were simply modified monocortical self-tapping screws. Because they required a drilled hole for placement, there were concerns about suboptimal placement and root damage that occurred during placement. The second generation self-drilling/self-tapping screws improved tactile feedback, limiting the possibility of root damage. Additionally, because power equipment is not needed, the system can be used outside the operating room (i.e. in the intensive care unit or emergency department). The manufacturer recommends placing screws above the root apices; however, the author has found that subapical placement led to mucosal overgrowth complicating their removal. Instead, the screws should be placed in a bicortical fashion between the roots at the level of the mucogingival junction. It is recommended, if possible, to obtain a panorex film prior to placement of the screws in order to evaluate the root morphology. When possible, at least one screw should be placed proximal and distal to the fracture. However, multiple screws can be placed to direct the vectors of the interarch wires appropriately which in turn aids in fracture reduction and stabilization. Since their introduction, they have been met with both enthusiasm and criticism. Recent reports have illustrated several

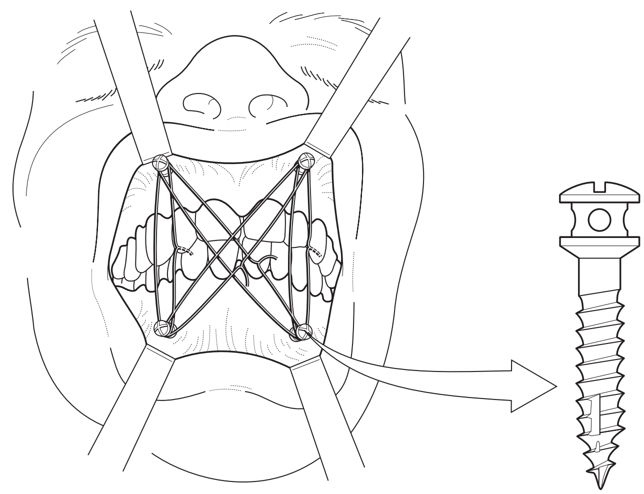

Figure 52.2 Intermaxillary fixation screws.

inherent risks and limitations which include root injury, screw loosening, screw shearing and aspiration. The self-drilling feature offers a greater degree of tactile feedback during placement, allowing the operator to change insertion location before root damage occurs. In paediatric patients, the IMF screws should be avoided or used with caution to prevent injury to the tooth buds.

External mandibular fixation

External mandibular fixation has played an important role in the management of comminuted mandible fractures, infected mandible fractures and maintaining continuity defects secondary to infected osteoradionecrosis (Figure 52.3). However, through the advancements made with rigid fixation, as well as microvascular reconstructive surgery, this technique has waned in its use. In circumstances which are relative contraindications to internal rigid fixation (i.e. infected hardware) where the surgeon is attempting to optimize soft-tissue health, the external fixator functions to maintain the mandibular continuity defect, as well as eliminating any foreign body within the wound bed. Once soft-tissue stabilization is achieved, the definitive repair can take place and the external fixation removed.

First-generation external fixators utilized transcutaneous bicortical pins (placed along the inferior border) which were then bridged by filling an endotracheal tube with acrylic resin. Today's second-generation systems still use similar types of pins, but instead use alloy bars or carbon fibre, with locking clamps to finalize the fixation. These fixators are less cumbersome with streamlined instrumentation. One advantage is the ability to perform minor adjustments to address malocclusions, by simply loosening the clamps, placing the patient into MMF and retightening the clamps.

The technique to place the fixator is as follows:

- Placement into MMF if indicated.
- Palpation of the inferior border proximal and distal to the continuity defect.
- A stab incision with a No. 15 blade where pins are to be placed.
- Blunt dissection to the inferior border with a haemostat.
- Placement of transcutaneous trocar.
- Drill bicortically with appropriate size drill bit.
- Measure width of inferior border with depth gauge.
- Place appropriate length bicortical pin.
- After all pins are placed, attach clamps and precontoured bar.
- Release MMF and verify occlusion.

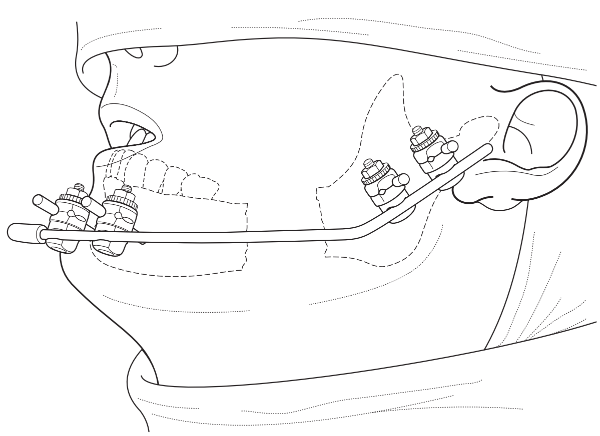

Figure 52.3 External mandibular fixation.

RIGID INTERNAL FIXATION

Non-locking plates/screws

Rigid fixation utilizes bicortical screws and rigid plates (2.0–2.4 mm) along the inferior or posterior border of the mandible, with or without a second monocortical plate (typically a miniplate) placed in the subapical region or external oblique ridge. This plate is termed a 'tension band' because of its use in an area of biomechanical tension. Rigid fixation should not require the use of post-operative MMF. Depending upon the circumstance, rigid fixation can be placed either through a transoral/buccal (described in section 'Miniplate (Semi-Rigid) Fixation') or transcervical approach, the author's approach is as follows:

- Local anaesthesia and muscle relaxation is avoided during this dissection to allow localization and protection of the marginal mandibular branch of the facial nerve.
- A curvilinear incision is based at least 2 cm inferior to the inferior of the mandible within a skin crease.
- The marginal mandibular branch is superior to the inferior border of the mandible once it passes to the anterior facial vessels. However, when it is posterior to these vessels the nerve is within 1 cm below the inferior border 19% of the time.
- Incision is made through the skin and subcutaneous tissue to the level of the platysma.
- Dissection continues through the platysma to the level of the superficial layer of the deep cervical fascia.
- In addition, the external jugular vein and greater auricular nerve are identified overlying the sternocleidomastoid muscle (SCM).
- The superficial layer of the deep cervical fascia is incised, the facial vein is identified and is then clamped, divided and ligated. The distal aspect of the vein is left on a long silk tie and is gently retracted superiorly with this suture. This manoeuvre retracts the nerve (which is superficial to the vein in the cervical fascia) superiorly protecting it from injury.
- The facial artery is identified at the posterior/superior aspect of the submandibular gland. It is then clamped, divided and ligated.
- The fascial plane overlying the SCM is followed to the angle and posterior border of the mandible.
- In the submental region, the fascial plane overlying the anterior belly of the digastric is followed superiorly to its attachment at the symphysis.

- The periosteum and masseteric sling is then incised and a subperiosteal plane of dissection is then performed to expose the mandible.

Almost all the screws manufactured today for use in the mandible are self-tapping in design. A plating system is defined by the diameter of the screws; depending on the manufacturer, the diameters used for mandibular repair will range from 2.0 to 3.0 mm. The non-locking plates/screws are designed to act as separate units working in conjunction with one another to establish a stabilized fracture. When non-locking screws are tightened, the heads of the screws exert pressure upon the plate which provides stabilization across the fracture. This design is effective, but is not without potential consequences. The pressure generated by the screws is translated through the plate to the underlying bone (Figure 52.4). This has the potential to cause bone resorption beneath the plate. If this occurs prior to the time required for primary bone healing, the hardware can then fail, increasing the risk of non-union, malunion, malocclusion and infection. In addition, poor technique with plate adaptation and utilizing non-locking screws can increase the potential for fracture displacement (Figure 52.5). This occurs when the screw head comes into contact with the plate during the tightening process. This action pulls the fracture segments to the plate, resulting in displacement of the segments and malalignment. There are specific situations where this feature can be used to the surgeon's advantage, such as reducing the lingual splay of symphyseal fractures caused by muscle pull. In these situations, the plate can be intentionally overcontoured and the use of non-locking screws will help reduce the lingual cortex (Figure 52.6).

Locking plates/screws

The introduction of locking plates/screws has addressed some of the issues discussed earlier (Figure 52.7). The locking plate/screws have two sets of threads, bone threads and

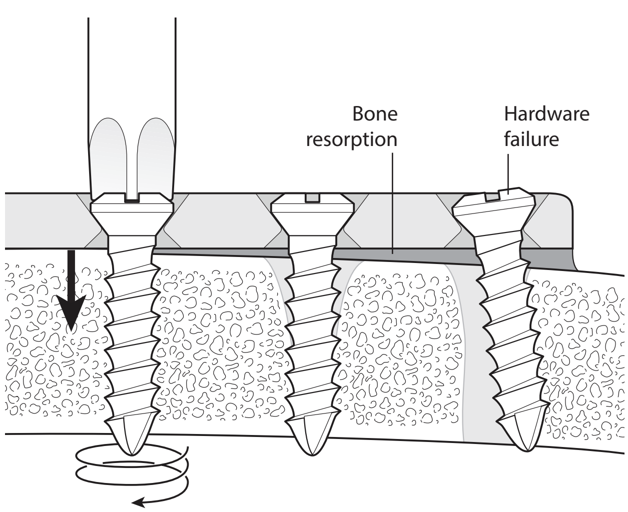

Figure 52.4 Non-locking plates/screws.

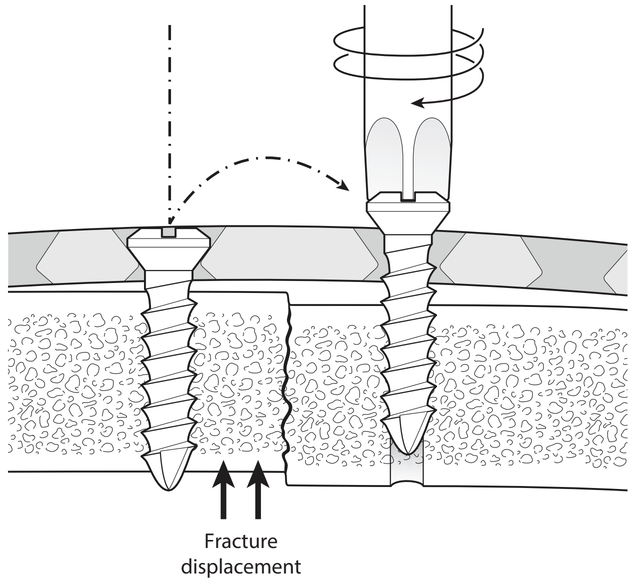

Figure 52.5 Non-locking plates/screws.

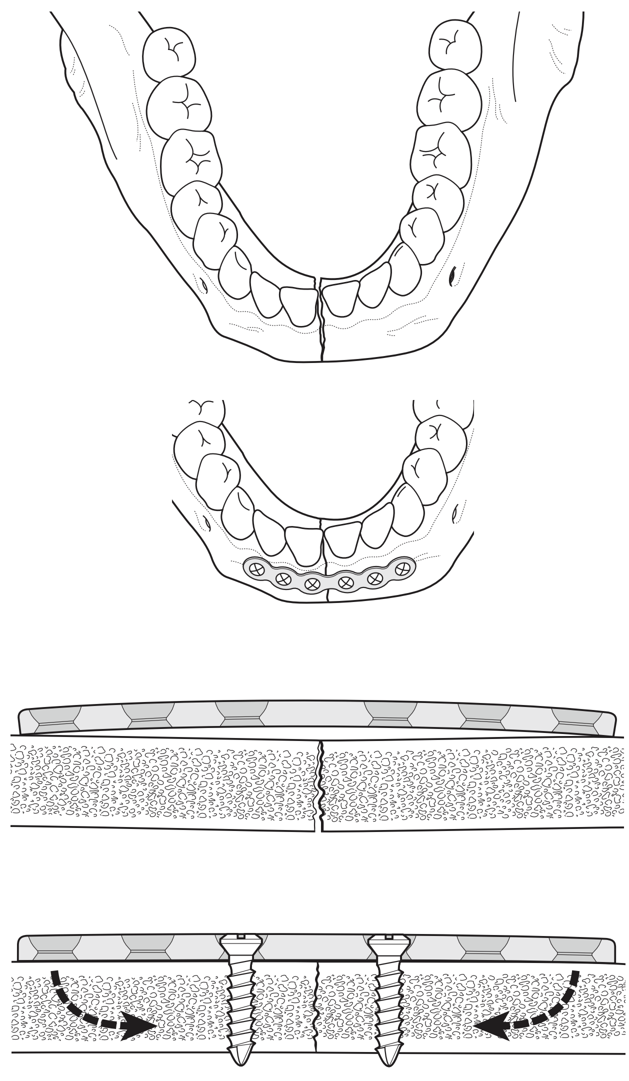

Figure 52.6 Non-locking plates/screws.

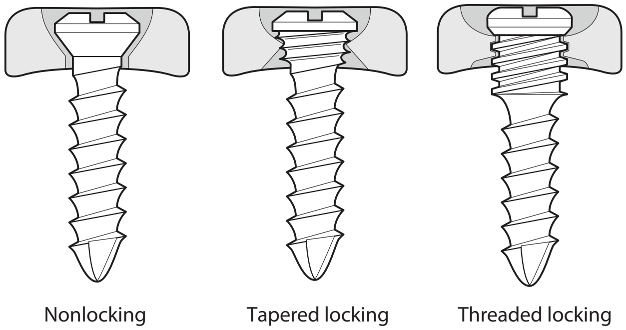

Figure 52.7 Locking plates/screws.

plate threads, which are threads in the head of the screw. This second set of threads unifies (locks) the screws to the plate creating a single rigid functional unit. Some feel this type of design is more stable and predictable to use. It creates a system which eliminates pressure being translated through the plate and underlying bone, thereby decreasing the likelihood of bone resorption and hardware failure. In addition, should any gaps exist between the plate and bone due to imprecise bending, this system is theoretically more forgiving, with less likelihood of fracture displacement, although studies indicate displacement is still possible with locking plates.

There are two types of locking designs available, the threaded and tapered systems. Each uses the same principle of locking the screw to the plate; however, the actual mechanics vary, giving each a relative advantage and disadvantage. In the threaded design, the plate itself also has machined threads, so that these screws are placed perpendicular to the plate. The second set of screw head threads mesh with the plate threads creating a locking system. When using locking technology in ablative surgery, the manufacturers recommend limiting the number of times the same screw is reinserted to three attempts. In addition, although these screws should be placed perpendicular to allow the threads to mesh appropriately. Some manufacturers state that the screws can be angled in limited access cases, essentially allowing the screw/plate to cross-thread.

Most recently, tapered locking plates/screws have been introduced, where the threads in the head of the screw are tapered and, depending on the manufacturer, there is either a single machined thread within the plate or no machined threads at all. The threads in the head of these screws will either cut its own thread pattern into the plate as the screw is being seated, or upon the last turn of the screw a single thread will engage the plate, providing a locking mechanism. It is suggested that one of the advantages of the tapered locking design is the freedom to place the screws at up to a 10° angulation from the plane perpendicular to the plate. This alleviates the risk of cross-threading and security of the locking mechanism. This may be advantageous when access is limited, although the author rarely finds this to be an issue.

A theoretical advantage of the tapered locking design is its ability to compensate for thread/hole distortion. This potentially occurs during the adaptation and bending process of

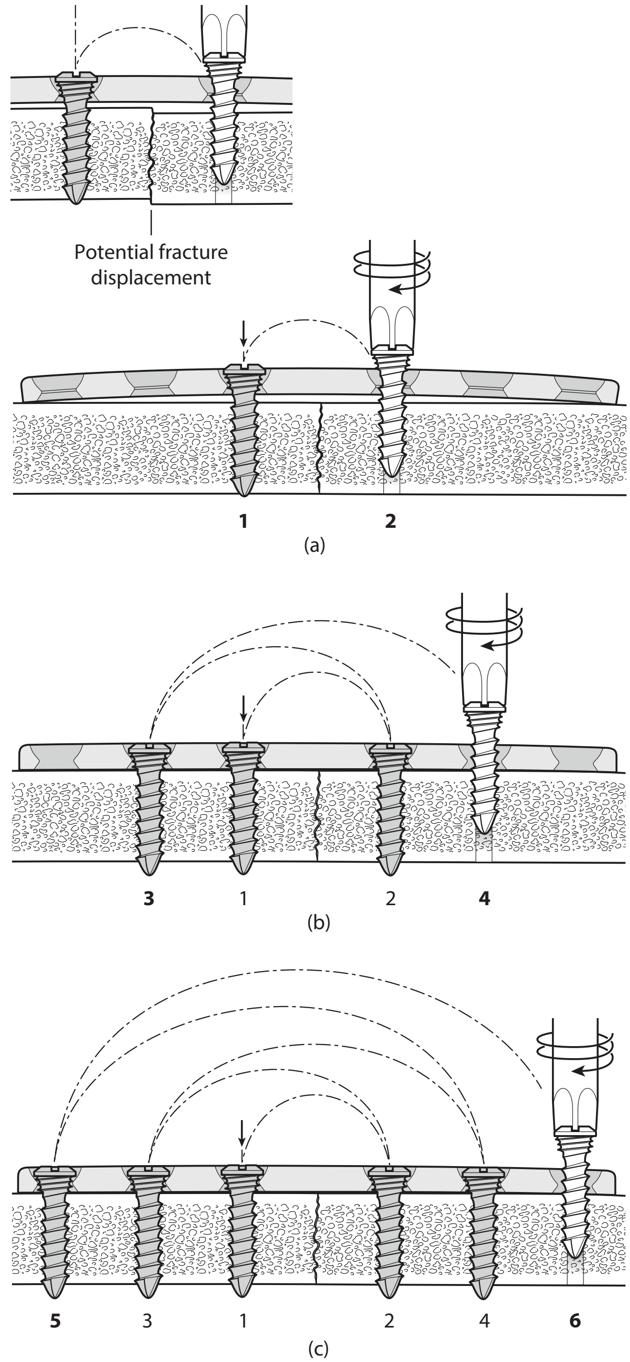

Figure 52.8 Locking plates/screws.

the plate. To help alleviate this problem with the threaded design, some manufacturers have fabricated bending inserts which are screwed into the plates during the contouring process, and are later removed. In practical application, the amount of distortion remains unknown, because the plates are bent between the screw holes, not directly over them. If, however, thread/hole distortion in the plate is considered a clinical concern, the concept of a tapered screw design might alleviate this issue. In order to prevent the possibility of fracture displacement, the author recommends a modification of the manufacturer recommended sequence of screw placement (Figures 52.8 and 52.9).

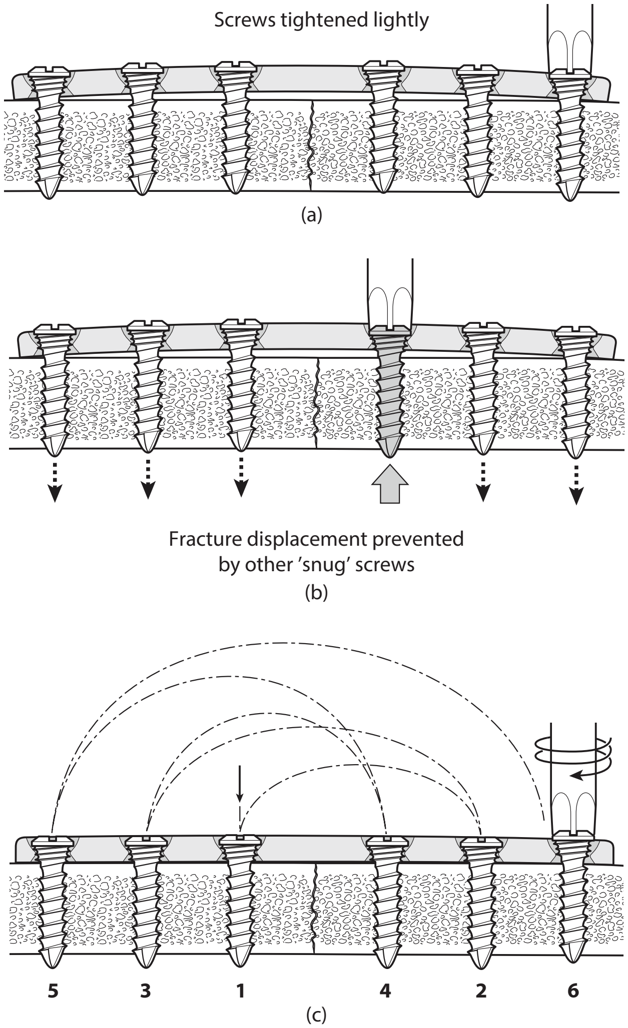

Figure 52.9 Locking plates/screws.

Although the theory behind the design of locking plates/screws is plausible, presently there is lack of clinical data to support their superiority to its non-locking counterpart when used in mandible fracture repair. However, the use of locking technology for mandibular continuity defects has been shown to be of benefit when compared to its non-locking counterpart.

Miniplate (semi-rigid) fixation

Semi-rigid fixation is the employment of miniplates and monocortical screws for the treatment of fractures and dentofacial deformities of the mandible. The term 'semi-rigid' is reserved for the load-bearing areas of the mandible; however, these miniplates are considered rigid forms of fixation when used for upper and midface trauma because of the non-load-bearing features of these regions. Semi-rigid fixation has been described as an effective form of treatment of mandible fractures when placed along the lines of osteosynthesis. The lines of osteosynthesis are biomechanical points of compression, tension or torsion (depending on the region of the mandible). This technique has undergone modifications since its introduction and it utilizes a transoral and/or transbuccal approach (Figures 52.10 and 52.11) and can involve a single malleable plate or three-dimensional ('box') plate, with 2.0-mm diameter monocortical screws proximal and distal to the fracture.

Transoral approach

The transoral approach involves the following:

- Local anaesthesia and vasoconstrictor are injected along the planned incision (if not contraindicated).
- Incisions are based in the mandibular vestibule at least 5–7 mm inferior to the mucogingival junction to facilitate ease of closure and prevent dehiscence.
- The dissection is performed through mucosa, submucosa, mentalis or buccinator muscle (depending on the location of the fracture) and periosteum.
- A subperiosteal plane of dissection is then performed to the inferior border of the mandible.
- The mental nerve is identified in the premolar region and the nerve sheath is carefully skeletalized with a scalpel or tenotomy scissors. This is to allow for mobilization of the nerve and to prevent possible avulsion from the foramen by retractors.
- The fractures are mobilized, and any soft tissue entrapped within the fracture is removed, care is taken not to injure the inferior alveolar nerve.
- The patient can then be placed into MMF.
- Bone-reducing forceps can be utilized in the transoral approach to assist in fracture reduction within the parasymphyseal region. They are difficult to use in the angle region due to limited access.

Transbuccal approach

The transbuccal approach involves the following:

- The approach is essentially the same as the transoral approach.
- In the posterior mandibular regions, a transbuccal approach with the transbuccal trocar system is used to facilitate placing the screws as perpendicular to the plate as possible.
- A stab incision is made on the cheek overlying were the anticipated hardware is to be placed.
- Blunt dissection through the masseter and periosteum is performed with a haemostat.
- The trocar system is then placed in a non-traumatic fashion and the cheek retractor is assembled to the trocar handle.
- Fixation is then applied.

In its classic form, the 'Champy technique' uses a single plate in the subapical region or along the external oblique ridge when fractures are posterior to the mental foramen.

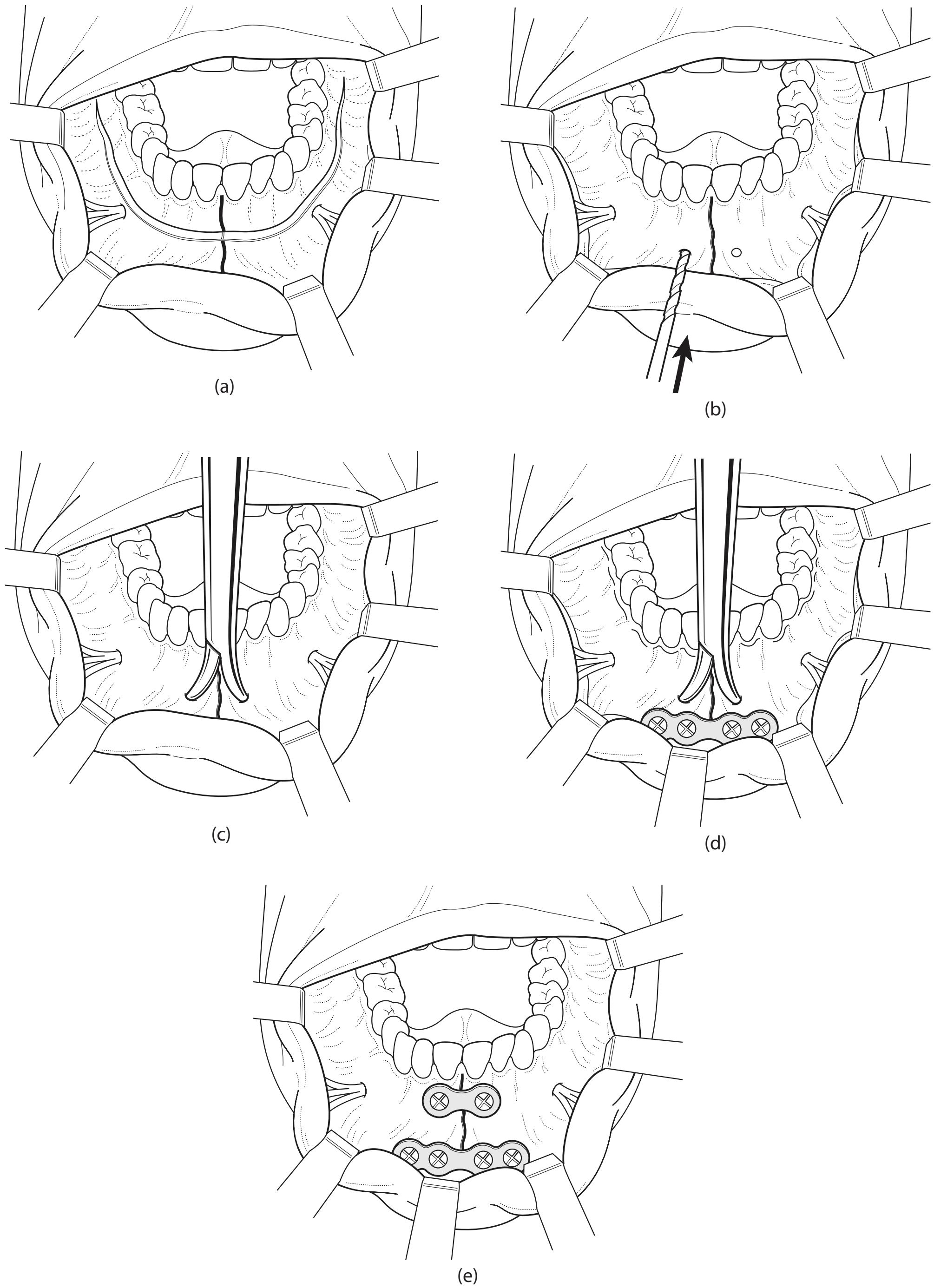

Figure 52.10 Transoral approach.

When treating parasymphyseal fractures (anterior to the mental foramen), two miniplates are used in order to resist the forces of torsion seen in this region. The first plate is placed in the subapical region and the second plate 5 mm inferior to the first. Miniplate fixation is not recommended in cases that lack adequate buttressing of bone or situations were patient compliance is doubtful.

When miniplates are used in the upper and middle facial thirds, the size of the plate/screws used varies from 1.0 to 2.0 mm. This is typically dependent on the region being fixated, as well as the manufacturer of the plating system. The types of screws used for miniplates are either self-tapping (which require pre-drilling) or self-drilling. Again, the circumstances (i.e. bone quality, pattern of fracture) will determine the type of screws used with the miniplate.

Positioning screws/lag screws

Another form of rigid fixation is the use of positioning or lag screws (Figures 52.12 and 52.13). This form of fixation

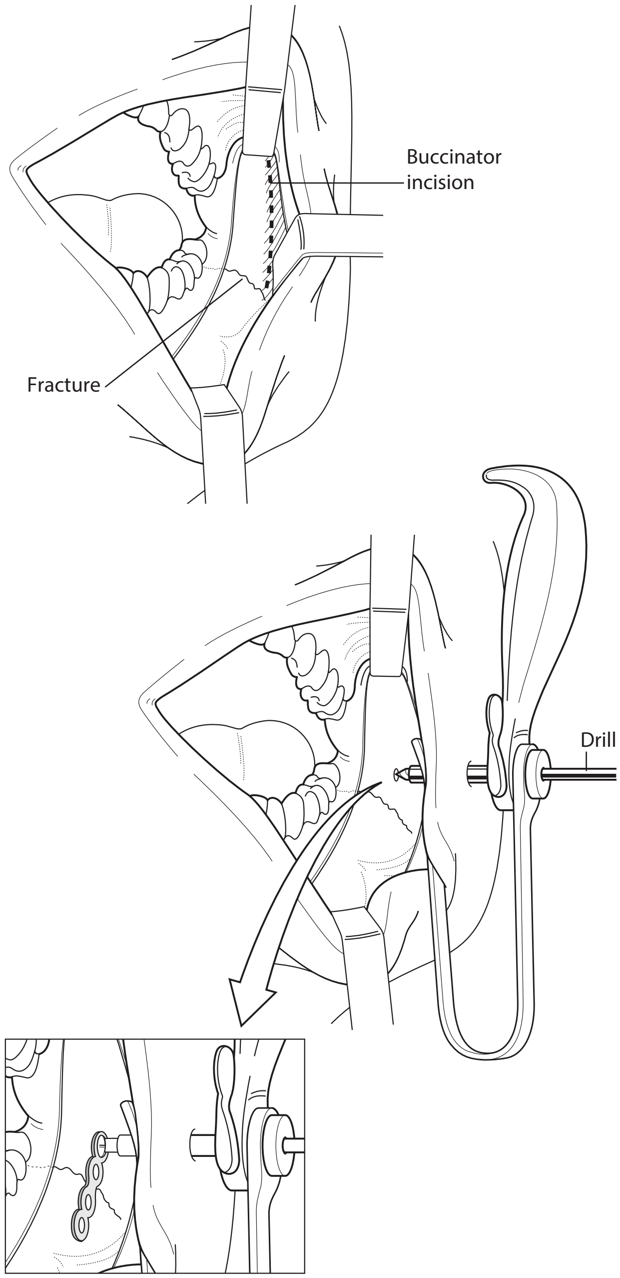

Figure 52.11 Transbuccal approach.

is typically used in orthognathic surgery of the mandible, bone grafting procedures and specific patterns of mandible fractures. The lag screw engages the inner cortex of the bone alone, so the head can apply compressive forces along its axial length. Positioning screws engage both cortices and do not apply the same compressive forces seen with lag screws; they fixate the bone in a more neutral position. When utilizing the position screw, the segments of bone are approximated (i.e. sagittal split osteotomy, bone graft), the bone is pre-drilled with the appropriate size bit prior to screw placement. Proponents of positioning screws for sagittal split ramus osteotomies feel there is less potential for compression of the inferior alveolar nerve and less

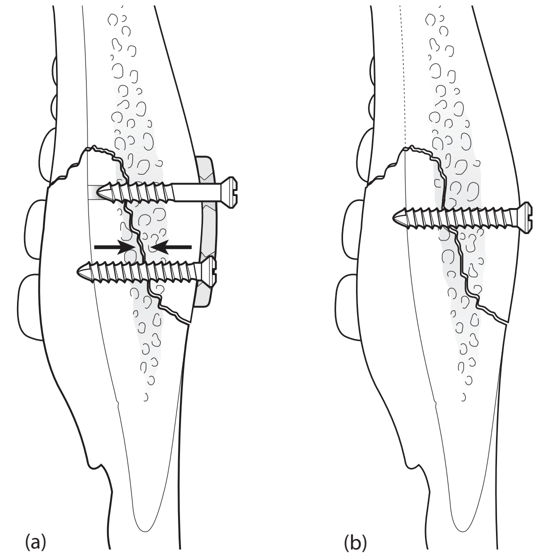

Figure 52.12 Positioning screws/lag screws.

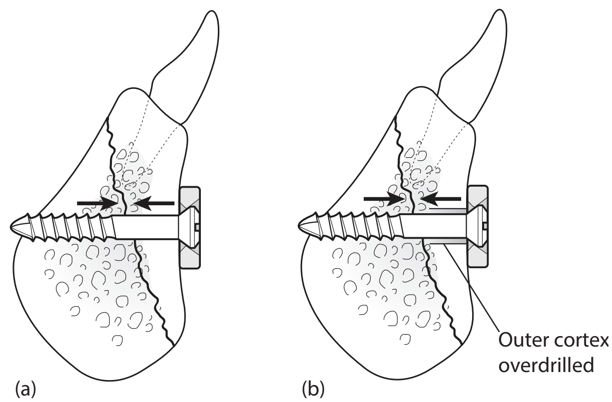

Figure 52.13 Positioning screws/lag screws.

torquing of the condyle from the fossa (more likely occurring with flared rami). When fixating these osteotomies, three screws can be placed along the external oblique ridge; or a triangulation technique can be employed with two screws along the external oblique ridge and one at the inferior border. Due to the nature of the positioning screws, one can experience a false sense of security because the screw can appear tight even if it is stripped from one of the cortices. For this reason, the surgeon must be aware of the screw engaging both cortices upon insertion.

There are two different ways to apply lag screws: one requires more bone preparation by the surgeon, the other uses a premanufactured lag screw (which requires less bone preparation). In order to be effective, the screws must be placed perpendicular to the fracture line. The diameter of lag screws can range from 2.3 to 3.5 mm and lengths vary depending upon the application. In the first method, both cortices are pre-drilled, but the proximal cortex is drilled to a larger diameter than the screw. This assures

that only the distal cortex is being engaged so the screw head can compress the inner and outer cortices together. The second method relies on a manufactured lag screw which has threads only on the distal half of the shank; the proximal half is smooth. After the bone is pre-drilled, only the distal half has threads which engage the inner cortex, allowing the head of the screw to apply compressive forces to both cortices.

Lag screws have been described for fracture fixation in every region of the mandible. They are ideal for symphyseal fractures which have stable buttressing. Ideally, two screws are placed parallel to each other and perpendicular to the fracture line, in order to resist the forces of torsion within this area. Countersinking the outer cortex is recommended to allow the screw head to sit flush with the bone. Some manufacturers provide washers to be used under the screw head to prevent the compressive forces from submerging the screw head beyond the lateral cortex into the medullary space. If this occurs, the technique is rendered ineffective and retrieval of the screw is difficult.

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Management of facial soft-tissue injuries

SIAVASH SIV EFTEKHARI and R BRYAN BELL

CONTENTS

INTRODUCTION

The management of facial soft-tissue injuries is a critical component of trauma care. There is great variability in complexity, with some superficial injuries requiring little more than a dressing or simple re-approximation, and other avulsive wounds requiring the transfer or local, regional or distant tissue flaps.

A basic understanding of wound healing process is necessary when repairing facial soft-tissue injuries. Wound healing can be divided into three phases:

1. *Initial Lag Phase (up to day 5):* No gain in wound strength. Wound is dependent on epidermal cellular adhesion and sutures to maintain closure.
2. *Fibroblastic Phase (days 5–14):* Rapid increase in wound strength.
3. *Maturation Phase (day 14 and onwards):* Connective tissue remodelling.

Tensile strength of the soft tissue is only about 3%–7% of normal by the end of the second week of healing after the sutures are removed. This increases to about 20% by the end of the third week and 50% by the end of the first month. Wounds never regain more than 80% of the strength of intact skin. Since wounds do not gain adequate strength until about 5–6 days after repair, it is important to know that the majority of the burden of approximating the tissue during this period rests on the sutures used. Therefore, the suture material and suturing technique used are very important parts of treating facial soft-tissue injuries. Suture material can be classified as absorbable or non-absorbable, coated or uncoated, natural or synthetic and multifilament (braided) or monofilament.

CLASSIFICATIONS OF SOFT-TISSUE WOUNDS

Lacerations: Usually have sharp edges. Washout with water and debridement, primary closure is layers should be performed. Lacerations can be broken down into several categories:

1. Simple Lacerations: good tension-free closure must be achieved.
2. Stellate Lacerations: caused by blunt, crushing trauma. Usually have ragged edges which need to be cleaned and the edges sharpened.
3. Flap-like Lacerations: these are avulsion injuries without the loss of tissue.

Contusions: Refers to the bruise caused by edema and haematoma in subcutaneous tissues resulting from blunt compressive injuries. Usually they require no treatment unless the haematoma becomes infected.

Abrasions: Caused by superficial damage to the skin no deeper than epidermis via mechanisms such as scrapping. Keeping the wound clean and moist is usually all that is required for treatment. Usually the skin epithelializes in 7–10 days following the injury.

Avulsions: This type of soft-tissue injury involves some level of tissue loss. Minimal tissue loss usually is of little consequence as undermining the surround tissue still allows for tension-free primary closure. Larger areas of tissue loss may require skin graft, local tissue flaps or free tissue transfer. Facial wounds should never be allowed to heal via secondary granulation as these create very unaesthetic results with scarring.

Facial wounds can be categorized as clean or contaminated. Fresh clean wounds are usually in no need of prophylactic antibiotics. The rate of infection increases and is directly related to the length of time that has elapsed since the initial injury. Skin wounds are usually contaminated with *Streptococcus* and *Staphylococcus*. Wounds that involve mucosal lining of the oral cavity are contaminated by oral flora. Through-and-through lacerations between oral cavity and facial/neck skin are considered contaminated. The number of bacteria present in the wound is more important than the type of bacteria in causing infections. Simple lacerations and abrasions have low bacterial content and very low chance of developing infection. On the other hand, crushing injuries, presence of foreign bodies in the wound, oro-cutaneous communication and animal or human bites lead to increase number of bacteria and much higher rates of infection. Additionally, it is very important to evaluate the immune status of the host and consider the comorbidities as well including poorly controlled diabetes, history of steroid use, malnutrition and so on. In these cases, antibiotic prophylaxis should be considered.

INITIAL EVALUATION

The initial evaluation of the trauma patient is well described by the American College of Surgeons Committee on Trauma. Once the airway is established, breathing confirmed and haemorrhage controlled and adequate circulatory volumes established, a secondary assessment of the maxillofacial region is performed.

Haemorrhage from the facial soft tissues is readily controlled with direct pressure and occasionally ligation of bleeding vessels. Epistaxis associated with concomitant midface fractures can be life threatening and should be managed with formal nasal packing or balloon occlusion devices (see Chapter 16).

After the patient is initially stabilized and haemostasis achieved, the facial wounds should be inspected closely. The wounds should be pulse irrigated with saline or balanced salt solutions. It is not the type of irrigation solution used that effects wound infection, but the mechanical action of high pressure irrigation that is important for successful outcomes. The use of undiluted hydrogen peroxide as an irrigant should be avoided as it inhibits wound healing and may cause tissue necrosis. Scrubbing of the wound with a brush may be undertaken if necessary but should be done sparingly to spare further damage to soft tissues. All devitalized soft tissue should be debrided and excised, and sharp healthy wound margins should be obtained to facilitate closure with minimal scarring. Devitalized tissue increases the local inflammatory response and subsequent scarring.

During final examination, it is imperative to assess cranial nerve function and to document injury to vital structures, such as the eye and brain. Various nerve function grading systems have been described, most notably the House–Brackmann score for facial nerve function. A nerve stimulator may be helpful in assessing the integrity of nerve branches. Consultation with subspecialists in ophthalmology and/or neurosurgery should be obtained as indicated.

PRINCIPLES OF SOFT-TISSUE REPAIR AND WOUND HEALING

Clean wounds may be closed primarily up to 48 hours following the initial injury. A relatively short delay in the definitive repair of soft-tissue injuries may be indicated if the underlying facial bones have been fractured and require surgical reduction. Temporary repair of the lacerations will minimize the risk of wound infection and prepare the wound bed for skeletal surgery on a semi-elective basis.

Primary wound closure should almost always be attempted if feasible. Wounds should be closed in layers if possible to place minimum tension on the superficial skin closure and aid in the eversion of skin edges to minimize scar widening. Tension across a wound decreases blood flow which leads to necrosis of wound edges and increased connective tissue growth in the proliferation phase and to widening of scars in the remodelling phase. Skin flaps should be appropriately undermined so wound edges can be everted which will minimize scar depression. Achieving good haemostasis is critical, as haematoma formation is a major cause of infection and wound break down. If adequate haemostasis cannot be achieved, then drain placement should be considered.

Delayed primary wound closure is usually indicated in patients that have extensive high-energy tissue loss and/or devitalized tissue, such as those caused by high-velocity gunshot wounds. These wounds generally require serial washouts and debridement before primary closure can be attempted. Delayed repair of contaminated injuries and bite wounds to the face is not recommended, as early primary closure results in less scarring. In the case of significant tissue avulsion, local flaps, regional flaps or free tissue transfer may be needed to adequately restore tissue to previous form and function.

The following general guidelines summarize the management of soft-tissue injuries:

1. Perform adequate washout and debridement prior to definitive repair.
2. Handle tissue gently to minimize trauma.
3. Achieve complete haemostasis.
4. When suturing, perform layered closure and ensure that skin margins are relaxed without tension and everted.
5. Use fine sutures such at 5-0 or 6-0 sizes should be used for skin and removed early usually between 4 and 6 days. 3-0 or 4-0 absorbable sutures can be used for deep sutures.
6. Properly align key landmarks, such as eyebrows and vermilion border of the lips for optimal aesthetic results.
7. Delay scar revision for a minimum of 6 months.

INJURIES TO FACIAL STRUCTURES REQUIRING SPECIAL TREATMENT

The lip

Injuries of the lip can cause aesthetic and/or functional problems. Accurate re-approximation the vermilion border of the lip, defined as the transition point between the mucosal tissue and skin of the lip, is critical to achieving an aesthetically acceptable result. An irregular vermilion border or mismatch of more than 1 mm becomes clinically noticeable. Deeper wounds to the lip should be closed in layers to re-approximate the orbicularis oris muscle as this muscle is important for oral function and lip competence.

Avulsive injuries to the lip can still be repaired primarily with minimal to no functional or aesthetic defects if no more than about 25% of the upper or lower lip is lost. For more extensive avulsive tissue loss, local flaps such as the Abbe–Estlander flap can be used to rotate tissue into the avulsed area. The Abbe flap is well suited for both upper and lower lip reconstructions and is generally indicated for repair of vertical defects of both vermilion and cutaneous lip tissue that do not involve the commissure. Injuries that involve the oral commissure can be reconstructed with a Karapandzic flap which is designed to re-establish the circumoral sphincter by rotating and advancing the remaining innervated orbicularis oris muscle. The Webster–Bernard flap is used to reconstruct the lower lip by advancing cheek tissue and the remaining lip tissue medially. This technique is well suited for subtotal defects of the lower lip where the commissure is preserved (see Chapter 38).

The ear

Initial evaluation of injuries to the ear should include examination of external and internal structures such as the tympanic membrane and a gross hearing exam to rule out sensorineural hearing loss. The pinna or auricle of the ear is the portion of the external ear most commonly involved in trauma. They consist of a thin central area of relatively avascular cartilage which receives most of its blood supply from the thin overlying layer of skin. This avascular cartilage providing the semirigid configuration of the auricle is a primary concern in the treatment and post-operative management of an ear injury. Meticulous approximation of both skin and cartilage is necessary to assure favourable wound healing and prevent chondritis or tissue necrosis. The cartilage should be covered by skin and a bolster dressing is generally recommended to minimize the risk of haematoma formation which can cause ear deformities such as 'cauliflower ear'. Leech therapy has also been proposed for haematoma management of the external ear with variable success rates.

Simple ear lacerations are usually easily treated under local anaesthesia. The general principles of wound repair are the same for the ear as they are elsewhere on the face. 5-0 or 6-0 monofilament sutures are recommended. In simple lacerations, there is usually no need for sutures in the cartilage of the auricle.

In partial ear avulsion, the type of reconstruction depends on the size of the defect and the region of the helix affected. In general, acquired defects of the superior auricle no larger than 2 cm can be repaired primarily by advancing the helix in both directions by making releasing incisions. Middle auricle defects 2 cm or smaller can again be closed primarily with the help of Burrow triangles to allow approximation of tissue without tension. Larger avulsive segments may require microvascular anastomosis, although it is very rare to find good vessels for anastomosis particularly in the avulsed segment. Depending on the amount of cartilage lost, a variety of techniques involving local skin flaps, contralateral conchal cartilage graft and rib cartilage graft can be used.

The treatment of avulsive ear injuries depends on the amount of tissue loss. For total avulsions the severed ear should be evaluated for the possibility of microsurgical reattachment. Other options included debriding the ear of all soft tissue and burying it in a post-auricular pocket to provide blood supply. This allows the ear to revascularize and re-epithelialize which then can be uncovered. Prosthetic rehabilitation of the external ear can also be considered in cases of significant tissue loss.

EYELID AND NASOLACRIMAL APPARATUS

The eyelids function to protect the globe from injury, maintain moisture and aide in channelling tears through the canalicular system. The anatomic layers of the eyelid include the skin, alveolar tissue, orbicularis oculi muscle, tarsus, septum orbitale, tarsal (meibomian) glands and conjunctiva. The grey line is defined by the junction of skin and mucosal membrane of the eyelid. Tarsal plate is important for eyelid support. The muscular layer overlying the tarsus is anchored to the lateral and medial canthal

ligaments. The orbital septum is attached to the periosteum circumferentially in support of the retro-orbital contents.

A thorough examination of the globe and lacrimal drainage system is needed whenever eyelid injuries are present. Injuries to the globe should be identified and appropriate treatment and referral to ophthalmologist performed. A thorough visual examination including visual acuity is very important.

Lacerations to the eyelid can be broken down into those that involve the lid margin and those that do not. Simple lacerations that do not involve the lid margin can be repaired primarily with small sutures, ideally 6-0 in size. Deep sutures are not recommended in the lower eyelid since inadvertent suturing of the orbital septum can lead to ectropion. If the attachment of the levator muscle to the superior portion of the tarsus is involved, care should be taken to repair this to prevent ptosis. In injuries where the lid margin is involved, accurate re-approximation of this structure is most important. The most important structures of the lid margin that must be realigned are the meibomian glands orifices, lash line and grey line.

Avulsive injuries to this region can be treated with full-thickness skin grafts from the post-auricular region which offers the best colour match. The eyelid avulsions can usually be closed primarily if less than 25% of the length of eyelid is lost. If more is lost then options such as a lid switch flap can be used. This is a two-stage procedure which transfers a full-thickness portion of the unaffected eyelid, together with the lashes, into the defect via a rotation. At the second stage, the pedicle is divided. Small injuries to the conjunctiva usually require no treatment. If the canalicular drainage system is involved, placement of silicone tubes through the severed tear ducts will preserve the drainage and prevent epiphora. One intact canaliculus is often sufficient to provide adequate drainage.

The nose

The nasal bone and cartilage are covered by muscle, subcutaneous tissue and skin with the internal lining of mucous membrane and glandular tissue. Proper examination of the nose requires use of nasal speculum with good lighting and suction. Epistaxis should be controlled and nasal bone fractures, septal haematoma and gross deviation of nasal septum have to be ruled out before repair of soft-tissue injuries. Nasal septal haematomas if present will need to be evacuated to prevent possible septal necrosis and nasal collapse/saddling. Closed reduction of a displaced nasal septum may be attempted in the clinic. Anterior traumatic nasal bleeding from the Kiesselbach's area is more common than posterior bleeding; they usually stop spontaneously, if not temporary nasal packing may be required. Use of vasoconstrictor sprays such as Afrin may be helpful as well for controlling small bleeds (see Chapter 16).

Soft-tissue repair of the nose is based on which subunit has been injured or deformed. A good understanding of nasal anatomy is crucial.

SURFACE ANATOMY AND NASAL SUBUNITS

- *Dorsum*: Radix to supratip break with lateral aspect merging with the nasal sidewalls
- *Tip*: Central aspect of the nose bordered by the other subunits and formed by the lateral genu of the lower lateral cartilages
- *Columella*: Middle and medial crura of the lower lateral cartilages extending from its junction with the upper lip philtrum superiorly to the nasal tip
- *Alae*: Consists of the lateral crus of the lower lateral cartilage and the soft tissue extending to the nasolabial crease
- *Sidewalls*: Extend from medial canthus to lateral edge of the nasal dorsum and lateral aspect merges with cheek skin; inferior aspect merges with the nasal ala and nasal tip
- *Soft triangles*: Soft-tissue depression inferior to the alar cartilage extending from apex of nasal aperture with no cartilage support

The deeper anatomy of the nasal complex is a combination of bony and cartilaginous support, starting from the bony radix of the nose and extending inferiorly and posteriorly into the lower lateral cartilages and the septal cartilage, respectively.

Tears in the internal mucosal lining of the nose should be repaired if possible with thin absorbable sutures. Exposed septal cartilage does not pose any difficulty as long as the mucosa is intact on the other side of the septum. Full-thickness lacerations of the nose should be repaired in a layered fashion, re-approximating the mucosa, cartilage and skin. Avulsive wounds of the nose with skin missing may be repaired with full-thickness skin grafts ideally from the post-auricular location. With larger more involved defects, local flaps such as nasolabial flap or paramedian forehead flap may be utilized.

The scalp

The anatomic layers are well described by the convenient acronym 'SCALP': Skin, Subcutaneous Connective tissue, galea Aponeurosis, Loose areolar tissue and Pericranium.

The first superficial three layers are united as one and difficult to separate. These three layers can easily slide over the loose areolar connective tissue layer which is a great dissection plane for the surgeon. Epicranial muscles, where present, lie between the galea and the loose areolar tissue. The pericranium is very vascular and deep full-thickness injuries to scalp can be a major source of blood loss. After good washout and achievement of haemostasis, layered closure of the scalp wound should be achieved. In

large contaminated avulsive injuries, use of drains should be considered. In avulsive scalp wounds, tissue survival is usually dependent on the amount of residual pericranial coverage of the skull. In cases where soft tissue is missing, local rotation/advancement flaps, skin graft or even vascularized tissue transfer can be considered.

FACIAL BITE WOUNDS

About 15% of animal bite wounds involve the facial structures. The majority inflicted by dogs involve children. They are considered complex injuries contaminated with a unique polymicrobial inoculum. These types of injuries usually fall into one of the following three categories:

1. Puncture wounds
2. Lacerations
3. Avulsions, with or without actual tissue defect

It is not uncommon to have a combination of the above along with some degree of crush injuries. Dog bites tend to be focused around the lips, cheek and nose. Human bites on the other hand tend to be focused mainly around the ears and lower lip.

Very similar principles are followed for repair of facial bite wounds as other injuries to the facial region. After thorough irrigation and debridement and achieving good haemostasis, single- or multi-layered closure is achieved if there are no obvious signs of infection. Local, distant free flaps or skin grafts can be used if there is significant tissue loss.

Fortunately, facial bite wounds generally display low infection rates due to the rich blood supply of the area. Puncture wounds can have higher infection rates since they involve deep inoculation of pathogens. Crush injuries can cause infections with lower bacterial counts in the wound due to resultant tissue ischaemia. Ear and nose human bite injuries have the highest infection rates due to the inevitable cartilage exposure.

Antibiotic prophylaxis is an important part of management of animal bites. Prophylaxis again *Pasteurella* spp. from dog and cat bites, and *Viridans streptococci*, especially *Streptococcus anginosus* and also *Staphylococci* and oral anaerobes from human bites is necessary. A close follow-up of these patients is needed.

SUMMARY

Facial injuries are very variable in nature and can involve many vital structures. Recognition of injuries to these vital structures of the face is extremely important. Accurate diagnosis and management of acute soft-tissue injuries will help to ensure optimal functional and aesthetic results. Care should be taken with proper and meticulous initial management to minimize complications. It is very important to pay close attention not only to restoring function but also achieving good cosmetic results.

ACKNOWLEDGEMENT

We thank Suhail K. Mithani and Eduardo D. Rodriguez for allowing us to use 'TOP TIPS' from second edition.

Top tips

Initial evaluation of the extent of facial soft-tissue injury includes thorough cleansing and removal of wound contaminants (e.g. dirt, glass).

- Lacerations can be repaired with up to 24 hours delay with excellent results.
- A low threshold should be maintained for taking a patient to the operating room for evaluation and repair of soft-tissue injuries.
- Photographic documentation of injuries and repair is imperative.
- Radiographic evaluation should be performed to rule out fracture or presence of foreign bodies.
- Avoid shaving the eyebrow to facilitate injury evaluation.
- All patients with periorbital injuries should be evaluated for ocular injuries.
- Avulsed or amputated tissue can often be restored successfully to the native.
- Re-approximation of the vermilion border should be performed prior to injection of vasoconstrictive local anaesthetic agent for repair of lip lacerations.

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Dentoalveolar trauma

ELIZABETH A KUTCIPAL

CONTENTS

INTRODUCTION

Dentoalveolar injuries are unique injuries. They can range from minor dental fractures to multiple avulsed teeth. Often, it is not clear if an injured patient should be taken to an emergency department or a dental/oral and maxillofacial surgery office. Many emergency room personnel are not familiar with treatment of dentoalveolar injuries or are not equipped to adequately treat them. Private offices may be well prepared to treat dentoalveolar injuries, but unable to treat other injuries. Oral injuries may have concomitant injuries as well, including soft-tissue lacerations or more significant neck, extremity or intracranial injuries. Dentoalveolar trauma is more common in younger patients; bony fractures are more common in older patients. This chapter focuses on dentoalveolar injuries.

PATIENT ASSESSMENT

When assessing a patient with an oral injury, the mechanism of injury is important. This may be a fall, assault, motor vehicle crash, sports injury etc. It is important to know how and when the injury occurred. This information is especially important if a tooth has been avulsed: how long the tooth has been out of the mouth and how it has been stored. In addition to the history of the injury, a brief medical history should be obtained. This would include medical history/co-morbidities, medications, past surgical history and allergies. The patient should be assessed for other injuries before focusing exclusively on the orofacial injuries. Orthopaedic injuries, neck pain, loss of consciousness etc. necessitate a visit to an emergency department. A systematic exam of the face/dentition helps to accurately and efficiently evaluate each patient. For example, initially, extra-oral injuries are documented. One method might be to evaluate the upper facial third, the middle facial third and the lower facial third. The upper facial third includes the forehead, eyes, orbits, eyelids etc. The middle facial third encompasses the nose, ears, zygomatic arches etc. The lower facial third includes the mandible, dentition and oral cavity. Sensory and/or motor deficits should not be overlooked. Once extra-oral anomalies are documented, the examiner can look intraorally. Again, this includes both the hard and soft tissues. The occlusion should be examined for mandibular step-offs or mal-occlusion indicating possible mandibular fracture. Evaluation of the floor of the mouth is important to look for ecchymosis or haematoma. If teeth are avulsed, it is helpful to account for the missing teeth to ensure they have not been aspirated or displaced into the adjacent soft tissues. If avulsed teeth are viable, they can be positioned back into the alveolus. The details of treatment will be outlined later in this chapter. There are a myriad of other dentoalveolar injuries that occur. A thorough systematic post-traumatic evaluation helps to avoid inadvertent unrecognized injury.

Imaging of the injured area may help to further assess the injury. Imaging modalities may be limited, depending on the location of the exam and the availability of resources. If adequate imaging is unavailable, timely follow-up is important. Dental radiographs evaluate the teeth for injury. These images show injuries that may not be noticeable by clinical exam. A root fracture is a prime example of this. A panoramic radiograph may assess for mandibular injuries, if they are suspected. Dentoalveolar fractures are sometimes difficult to see on conventional peri-apical radiographs and panoramic radiographs. A computed tomography (CT) scan may be warranted if more extensive injuries are suspected (Figure 54.1).

Figure 54.1 A paediatric patient in the mixed dentition sustained severely intruded teeth after falling while playing basketball (3D CT reformat).

When seeing patients with dental trauma, after an initial history and initial exam, the wounds should be cleaned. Cleansing may start with saline or chlorhexidine mouth rinse. Gentle debridement with gauze or a soft tooth brush removes debris and may identify additional injuries. Soft-tissue injuries should be addressed, if needed.

Dental trauma: The adult dentition

After the permanent incisors begin to erupt, the adult dentition is at risk for injury. The maxillary incisors are the most prominent teeth in the anterior dentition and have a high likelihood for damage. Ectopically erupting teeth or patients with a significant mal-occlusion may have even more prominent incisors. Dental injuries to the teeth have been well classified by Dr Ellis. To briefly review, an Ellis Class I fracture is an injury to the enamel of the tooth only. An Ellis Class II fracture involves the enamel and dentin. Ellis Class III dental fractures involve the enamel, dentin and pulpal tissues. Involvement of other dental specialists is often necessary for these injuries (general dentists, paediatric dentists, endodontists, prosthodontists etc.). This chapter focuses on luxations of the teeth, avulsion and dentoalveolar fractures.

Subluxation

The dentition is acutely traumatized, possibly resulting in tooth mobility. The tooth will likely have some blood near the gingival margin due to injury to the supporting structures. If the tooth is not mobile, no clinical treatment is warranted. If the tooth (or teeth) is mobile, a non-rigid splint may be placed for approximately 2 weeks. The patient should be advised to follow a soft diet and maintain good oral hygiene. Short-term and long-term follow-up is warranted after subluxation to evaluate for pulpal necrosis.

Intrusion

Intrusion occurs when the tooth is traumatized, pushing it into the alveolar process. This commonly happens with trauma directly to the incisal edge of the maxillary incisors. The treatment varies depending on the development of the tooth root and if the apex of the root is closed or open (Figure 54.1).

If the root apex is open then the tooth can be allowed to spontaneously erupt. If it fails to erupt spontaneously then orthodontic treatment for extrusion should be considered. As per the International Association of Dental Traumatology (IADT) recommendations, if the tooth is intruded more than 7 mm, the tooth should be re-positioned and stabilized with a flexible splint (Figures 54.2 and 54.3).

If the tooth has a closed apex, the treatment recommendations differ. If the tooth is slightly intruded (<3 mm), the tooth can be allowed to spontaneously erupt. The tooth should be monitored and if it does not begin to erupt then an orthodontic referral is warranted for consideration of forced orthodontic eruption. A tooth with a closed apex that is intruded more than 3 mm may be a candidate for orthodontic or surgical treatment. Again, if the tooth is intruded greater than 7 mm, surgical re-positioning is indicated with placement of a composite and wire splint (Figures 54.4 and 54.5).

For all of these injuries, follow-up is imperative for continued re-evaluation of the tooth vitality and timing of

Figure 54.2 The patient from Figure 54.1 with the teeth re-positioned and stabilized with a flexible splint (frontal view).

Figure 54.3 The patient from Figure 54.1 with the teeth re-positioned and stabilized with a flexible splint (occlusal view).

Figure 54.4 An adult patient with both intruded teeth and soft-tissue injuries after a mountain biking crash.

Figure 54.5 The patient from Figure 54.4 with the teeth re-positioned and stabilized with a composite and wire splint.

splint removal. Splint removal is generally approximately 4 weeks.

Extrusion

Extrusion of the permanent dentition occurs when the tooth is extruded from the alveolar socket. The incisal edge will be 'uneven' with the adjacent teeth. This tooth displacement may be a significant occlusal interference. Treatment of extruded teeth includes re-positioning of the tooth in the socket and securing it with a composite and wire splint. Given the nature of the injury, once the splint is in place, the patient's occlusion should be evaluated to avoid occlusal trauma to the affected tooth. The splint should be considered for removal after 2 weeks. Again, short- and long-term follow-up is imperative.

Avulsion

Dental avulsion is defined by a tooth that is avulsed from the alveolus in its entirety. The goal is to find and identify the missing tooth or teeth. Each situation is unique and should be treated on a case-by-case basis. Severe dental caries or periodontal disease may be a contraindication for replacing an avulsed tooth. Patients with severe medical co-morbidities or immunosuppression may not be candidates for replantation of an avulsed tooth. Debris should gently be removed from the tooth without scrubbing it. Scrubbing the tooth, especially the root may remove viable periodontal ligament (PDL) cells. If the patient is conscious and the site is amenable, the tooth should be placed back in the socket. Alternatively, the tooth can be placed in cold milk, Hank's balanced salt solution (a physiologic salt solution), saline or in the patient's vestibule (avoid water). The site needs to be in adequate condition for the tooth to be placed in the socket. If the alveolus is crushed, the tooth may not be able to be replanted. Once the tooth has been replanted, a flexible composite/wire splint should be placed. Depending on the specific situation, tetanus coverage should be verified with the patient.

Several different scenarios exist for the avulsed permanent tooth. The tooth can have a closed or open apex. The overall prognosis of the tooth is based on the viability of the PDL cells. The PDL cells viability depends on the time out of the socket and the type of storage medium (if any).

If the injured patient presents with the tooth already in the socket, the tooth should be examined for proper positioning, both clinically and radiographically (if possible). Once this is confirmed, a non-rigid composite and wire splint should be placed.

If the patient presents with an avulsed tooth with a closed apex in physiologic media, the tooth should gently be cleansed of debris. This cleansing should be done with care to avoid disrupting the PDL cells as much as possible. Once the patient is anaesthetized with local anaesthesia, the tooth should be positioned in the alveolus and secured with a flexible splint.

Patients presenting with an avulsed tooth with a closed apex that has been stored dry or in non-physiologic media have an increased challenge. The PDL cells are unlikely to be viable. Again, the tooth should be gently debrided, and the root bathed in 2% sodium fluoride for 20 minutes (minimum of 5 minutes), if available. In this scenario, the tooth has a poor long-term prognosis and is likely to ankylose. The long-term prognosis of the tooth should be discussed with the patient (and parents) at that time. An ankylosed tooth may help to preserve space and alveolar bone in anticipation of future dental implant placement. The tooth should still be positioned in the alveolus and stabilized with a flexible splint for 4 weeks.

If the avulsed tooth has an open apex, the treatment is similar. The tooth should be gently cleansed, then placed back in the socket. Topical antibiotics may improve the chance of revascularization. If available, the avulsed tooth is placed in a doxycycline solution (1-mg/20-mL sterile saline for 5 minutes). A flexible splint should be placed for about 2 weeks. Ongoing pulpal evaluation is important for evaluation of revascularization or pulpal necrosis and the need for endodontic treatment.

Similar to other dentoalveolar injuries, once the tooth is splinted ensure that the injured tooth is not in traumatic occlusion. The patient should be instructed to maintain a soft diet. Oral hygiene instructions are reviewed with the patient; chlorhexidine mouth rinse may be prescribed. When a tooth is avulsed and repositioned, the patient should be sent home with systemic antibiotics that are appropriate for the patient's age and weight (Figures 54.6 through 54.8).

Figure 54.6 A paediatric patient with four avulsed permanent incisors after a bike crash over his handle bars, axial CT.

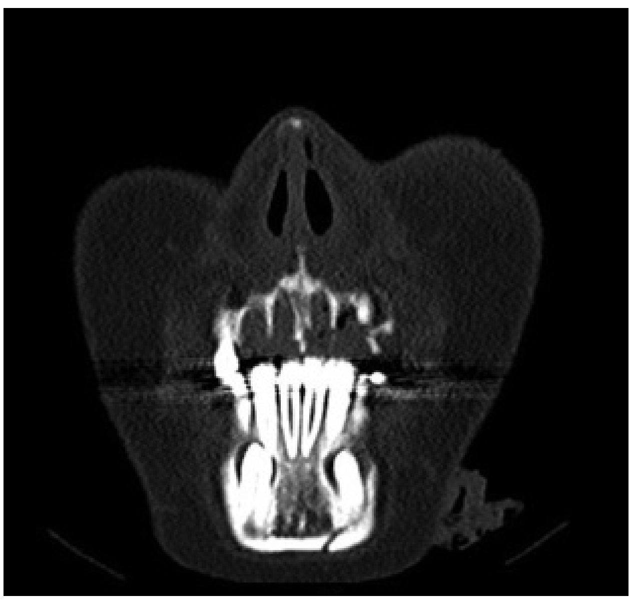

Figure 54.7 The patient from Figure 54.6, coronal CT.

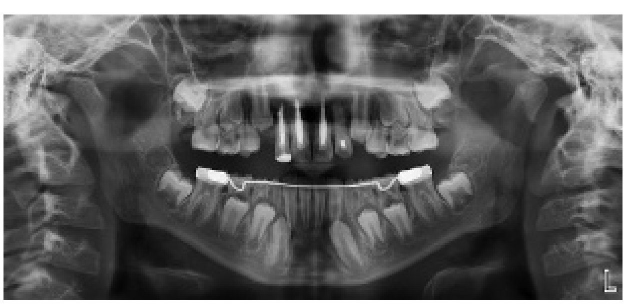

Figure 54.8 A panoramic radiograph of the patient in Figure 54.6, with the teeth repositioned. He is now in the process of endodontic treatment.

Root fractures

Root fractures occur with direct trauma to the crown. The fractures can occur in the cervical third of the root, the middle third of the root or the apical portion of the tooth. Root fractures in the cervical one-third of the root are difficult to treat. The tooth has a guarded to poor long-term prognosis. The crown of the tooth can be splinted to the adjacent teeth, although this is for an extended period of time: 4 weeks or more. Teeth with root fractures in the middle third or the apical third have an improved long-term prognosis, but still require long-term monitoring. These teeth can be splinted with a non-rigid splint, with re-assessment at 4 weeks after the injury.

Dentoalveolar fractures

A dentoalveolar fracture is a fracture of the alveolar bone. This injury may be in an isolated area or include several teeth. The fracture may or may not be visible on conventional dental radiographs. If a CT scan was obtained, the dentoalveolar fracture is generally visible; however, sometimes the bony injuries are subtle. The treatment recommendations vary depending on the source. The IADT recommends flexible splinting for 4 weeks. Peterson's text endorses rigid splinting for 4 weeks. Rigid stabilization of the fracture may involve the use of an Erich arch bar with interdental wiring. The teeth should be evaluated for occlusal trauma after splinting. Patients should be instructed to maintain a soft diet. Oral hygiene instructions should be reviewed. Chlorhexidine oral rinse may facilitate improved hygiene patients with dentoalveolar fractures. The splint should be considered for removal in 4 weeks. Systemic antibiotics should be considered, given the injury communication with the oral flora.

Follow up for dentoalveolar injurvies

Appropriate follow-up should be arranged for patients sustaining any sort of dentoalveolar injury. These follow-ups can range from clinical observation of the injury to root canals, orthodontic treatment, prosthetic rehabilitation etc. Appropriate instructions after a dentoalveolar injury may help the prognosis of the teeth: good oral hygiene, diligent follow-up and a soft diet. Good communication and a coordinated effort by all members of the dental team are imperative to achieve the best result possible.

Dentoalveolar trauma: Primary dentition

Similar injuries can occur in the primary dentition, some with differing treatment plans. The treatment plans are based on several factors. Aside from medical co-morbidities, treating a dentoalveolar injury may be based on the root resorption of the primary tooth and the potential injury of the developing permanent dentition. Traumatized primary teeth that are repositioned or remain in situ should be monitored until exfoliation for signs of pulpal necrosis.

Intrusion of primary teeth

Intrusion of the primary teeth is when the teeth are pushed into the alveolus. Intrusion of the primary teeth can affect the developing dentition, depending on patient age. If the crown of the intruded tooth is slightly pushed lingually, the root is pushed to the buccal, likely avoiding the tooth bud. In this case, the tooth can be left to spontaneously erupt. Conversely, if the crown of the intruded tooth is pushed to the buccal, the tooth root is potentially damaging the developing tooth. This tooth is indicated for extraction. The consequence of this injury is an enamel defect of the developing tooth.

Extrusion of primary teeth

Extrusion of a primary tooth happens when the tooth is extruded from the alveolus. This can be subtle in which case the tooth can gently be adjusted back into place. If the tooth is extruded more than several millimetres, the tooth should be extracted to avoid damage to the developing permanent tooth.

Avulsion of primary teeth

Unlike permanent teeth, primary teeth that are avulsed should not be replanted and splinted.

Dentoalveolar fractures in the primary dentition

Many factors are taken into account when treating dentoalveolar fractures in the primary dentition. If the affected teeth are near exfoliation or if repositioning may injure the developing teeth, extraction should be considered. If the segment can be effectively reduced, splinting of the segment may be an ideal treatment. Splinting requires a patient who can cooperate for the procedure and adequate isolation, if composite is going to be used. Treatment decisions are multifactorial when treating dentoalveolar fractures of patients in the primary dentition (Figures 54.9 and 54.10).

Figure 54.9 An axial CT of a dentoalveolar fracture of the left maxilla in a paediatric patient. Notice the roots of the primary teeth and developing permanent teeth.

Figure 54.10 A 4-year-old female who was playing and was struck in the mouth with her friend's head. She sustained a dentoalveolar fracture of the anterior mandible.

CONCLUSION

Dentoalveolar injuries come in all shapes and sizes. These can be as subtle as a tooth that has sustained a concussive injury without mobility or visible injury to significant dentoalveolar fractures requiring stabilization and possible tooth loss and reconstruction. No matter what the mechanism of injury, all patients should be thoroughly and systematically examined to ensure injuries are not overlooked. A recurring theme for all patients with dentoalveolar trauma is the need for appropriate and timely follow-up. For some patients, this follow-up would be a quick follow-up exam. For others, the follow-up can be extensive involving endodontic, orthodontic, surgical and prosthodontic input. Educating parents, coaches, emergency personnel etc. may help improve the prognosis of injured/avulsed teeth.

Quick dentoalveolar trauma resources:

- The Dental Trauma Guide: www.dentaltraumaguide.org, created by the International Association of Dental Traumatology.
- Guideline on Management of Acute Dental Trauma: www.aapd.org/media/Policies_Guidelines/G_trauma.pdf, Created and kept current by the American Association of Pediatric Dentistry.

Top tips

- The success of the treatment is directly proportional to the delay.
- Always check the soft tissues, particularly the lower lip for retained tooth fragments when teeth have been fractured.
- Remember that windscreen glass if often radiolucent.
- Great care must be taken when cleaning any avulsed tooth. The PDL cells on the root are very sensitive. Never scrub the root and avoid handling if possible.
- Root canal therapy should be undertaken at the first sign of root resorption.

SUGGESTED READINGS

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Mandibular fractures

CHRIS VINALL and MICHAEL PERRY

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INTRODUCTION

Applied anatomy

The mandible is important in airway maintenance, speech, mastication and deglutition. Fractures and injuries to the associated muscles can, therefore, result in considerable dysfunction and pain. Remember that in some instances – multiple fractures, or associated bleeding, soft-tissue swelling, alcohol intoxication and brain injury and in patients in the supine position (see advanced trauma life support [ATLS™]) – the airway may be placed at risk and needs careful and repeated evaluation.

Morphologically, the mandible is a U-shaped 'long bone' and can be divided anatomically into

- Symphysis
- Parasymphysis
- Body
- Angle
- Ramus and condyle

Of particular note are

- The many muscle insertions (which can either support or displace fractures)
- The teeth (which together with the periodontal ligament can act as a source of infection)
- The periosteum (which can assist fracture stability)
- The inferior alveolar (inferior dental) nerve (which together with the mental nerve, can be injured at the time of fracture, or during their repair) (Figure 55.1)

The muscles of mastication and the suprahyoid muscles are the principle movers of the mandible. Considerable forces can be generated; hence certain fractures can significantly displace and remain painfully mobile. Conversely, the thick, fleshy masseter and medial pterygoid muscles attach to much of the ramus and therefore splint fractures here. Ramus fractures (as distinct from the condyle) rarely need operative repair. The genioglossus (which forms the bulk of the tongue) and geniohyoid are attached to the midline genial tubercles – mobile fractures in this region may lead to loss of tongue support and airway compromise.

The canine teeth have long roots and the mandibular third molar teeth are often partially erupted. Together with the mental foramen, these factors can weaken bone locally and account for the frequency of fractures in these regions. In young patients, the periosteum may

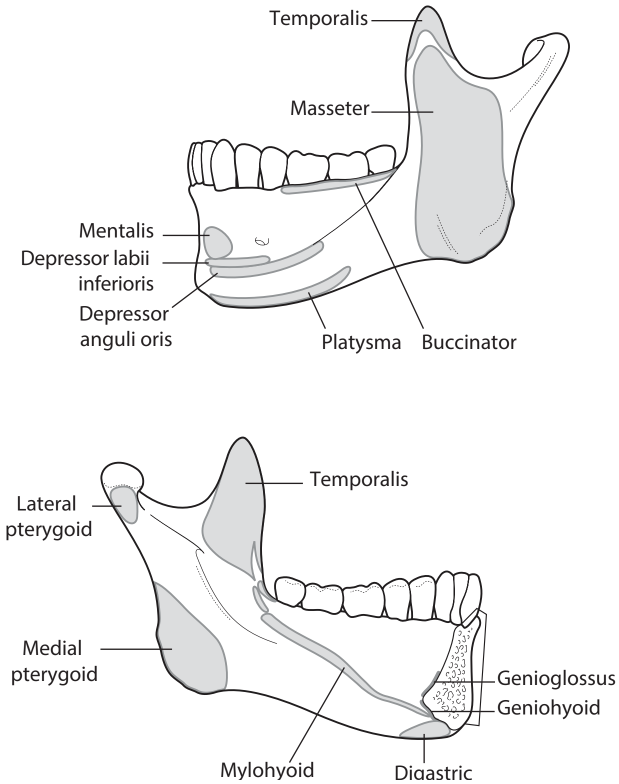


Figure 55.1 Outer and inner view of the mandible showing muscle attachments.

resist fracture displacement at the time of impact and in minimally displaced fractures may facilitate non-operative management. However, once it is torn (by injury or surgical exposure), fracture displacement can more readily occur.

COMMON FRACTURE SITES INCLUDE (PERCENTAGES MAY VARY)

- Condyle (36%)
- Body (21%)
- Angle (20%)
- Parasymphysis (14%)
- Ramus (3%)
- Alveolus (3%)
- Coronoid (2%)
- Midline symphysis (1%)

ASSESSMENT

'If you leave the patient facing towards heaven, it won't be long before they get there' (paraphrased, original source unknown). This aphorism, dating back to early times of major conflict, refers to the possibility of airway obstruction developing in patients placed supine following facial injuries.

Assessment of mandibular (and other) injuries commonly occurs in one of two scenarios:

1. High velocity injuries, where coexisting torso injuries exist and ATLS™ principles apply. Of direct relevance, here is immobilization of the entire patient and its potential affect on the airway.
2. The 'walking wounded', where other injuries have been ruled out.

In both scenarios, assessment always starts with the airway whilst simultaneously protecting the cervical spine until injury can be excluded. Although an appropriate verbal response is encouraging, direct inspection of the oropharynx must be undertaken. Oral bleeding and foreign bodies can be missed, which in the supine patient poses an obvious threat to the airway. In awake, supine patient's, blood may be swallowed initially, but if it continues it places the patient at risk of vomiting later (possibly at a time when they are under less supervision). In some mandibular fractures swallowing may be painful and ineffective. Correctly fitting rigid collars restrict mouth opening and make airway assessment difficult, but in all cases should be loosened to enable thorough examination. During this time, manual in-line immobilization of the neck must be correctly performed. Sizing of collars and careful application are also important. Correctly fitting collars can support some mandibular fractures, whereas poorly fitting ones can compromise the airway and exacerbate ongoing swelling.

In obtunded patients, the jaw thrust and chin lift are commonly performed to maintain the airway, but may be difficult with comminuted fractures. Those patients at high risk of vomiting may require intubation to protect the airway. However, not all patients vomit and the difficulty, therefore, lies in deciding who should have their airway secured as a precaution. This decision is even more critical if inter-hospital transfer or imaging (notably CT) outside the relative safety of the resuscitation room is necessary.

The hallmark of a mandible fracture is a change in the occlusion. However, a normal occlusion does not rule out a mandible fracture. Most fractures occur following blunt injury to the face, commonly following interpersonal violence in many countries. Sports injuries, falls and road traffic accidents are other frequent causes. Clinically the following signs may be elicited to varying degrees:

- Pain, especially on talking and swallowing.
- Drooling.
- Swelling.
- Altered bite.
- Numbness of the lower lip.
- Trismus and difficulty in moving the jaw.
- Loosened teeth.
- Mobility of fractured segment.

- Bleeding from the periodontium.
- Sublingual haematoma.
- With medial displacement of the condyle, injury to the trigeminal nerve can result in ipsilateral facial numbness (rare).
- The facial nerve may be damaged by a direct blow over the ramus, resulting in ipsilateral facial weakness (rare).

Imaging

Imaging studies are not required in every patient to rule out a fracture of the mandible. This would be the case in an alert and orientated patient in which a thorough clinical examination has confidently excluded any signs of fracture. However, when a fracture(s) is/are suspected, imaging will be required.

Deciding on the most appropriate imaging to evaluate the fracture/fractures depends on whether the patient presents with a suspected isolated injury or has suffered multiple trauma. If only an isolated fracture is suspected, the first choice would be to take two plain films of the fracture at right angles to the other. With the mandible, this is achieved by taking an orthopantomogram (OPT) and a posteroanterior (PA) view. However, plain radiography is not without its limitations:

1. Panoramic views in this region require a good technique and a co-operative patient who can stand, a requirement that may not be possible if the patient is intoxicated or has multiple injuries. In this case, an oblique view may be a better alternative.
2. Fractures of the condylar head are often especially difficult to see on any plain film view.
3. The symphysis is difficult to evaluate because of the overlap from the cervical spine. A lower occlusal view is useful for evaluating fractures in this region in particular the anterior lingual plate.

Computed tomography (CT) imaging may be indicated in the following circumstances:

1. High-energy injuries or in patients unable to undergo routine radiography (due to the presence of torso, cervical spine or brain injuries)
2. Complex fractures (e.g. comminuted fractures, craniofacial fractures or high condylar fractures that may be suitable for surgical repair)

Initial helical CT scan has been shown to identify 100% of mandibular fractures, whereas plain film panoramic imaging shows only 86% of these fractures. Recently, the use of cone-beam computed tomography (CBCT) has been reported as an accurate and reliable alternative to conventional CT, providing good quality images with less radiation.

The use of three-dimensional reconstructed CT scans (constructed from high-resolution thin sections of a CT scan) is particularly useful in evaluating the relationships of fracture segments preoperatively in panfacial injury management.

FIRST-AID MEASURES

Pain relief may be achieved by infiltration of local anaesthesia around the fracture, or if possible by an inferior dental nerve block. If the neck is ‘clear’, a soft collar can be used to support the mandible. ‘Bridal wires’ are the maxillofacial equivalent of a backslab in limb fractures (Figure 55.2). This is a tightened loop, or ‘figure of eight’ wire, encircling the teeth either side of the fracture. This, and/or intermaxillary fixation (IMF), should be considered when delays in repair (i.e. surgery the next day) are anticipated. Any loose dento-alveolar fractures should also be splinted.

TIMING OF SURGERY

Ideally, all fractures should be repaired as soon as possible, but this rarely happens. For all open fractures (e.g. overlying laceration, or involvement of the periodontium), it has been assumed that the longer the delay the more likely infection will occur. However, more recent studies have shown that a delay beyond 24 hours does not increase the risk of complications. By and large, in the absence of airway problems, active bleeding and excessively mobile (and painful) fragments, most patients’ surgery can be safely deferred until the next day. General anaesthesia can be risky and is best avoided late at night.

TREATMENT PRINCIPLES

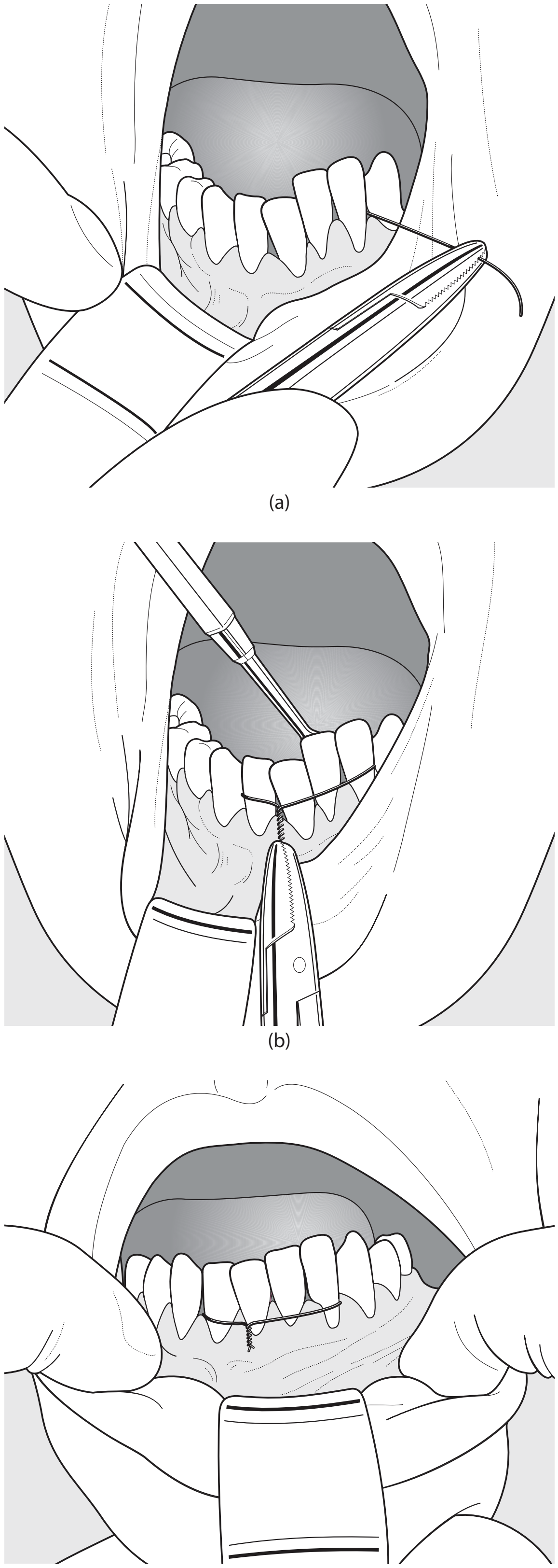
Treatment can be considered as either ‘closed’ or ‘open’.

Closed treatment

- Analgesia
- Antibiotics in open fractures (for 1 week)
- Soft diet until a firm callus forms (usually around 4–6 weeks)
- IMF, if required

Indications for closed treatment

- No or minimal displacement
- No or minimal fracture mobility
- Ability to obtain pre-injury occlusion
- No infection
- Good patient co-operation and follow-up



(a)

(b)

(c)

Figure 55.2 Bridal wires. (a) Pass wire as a figure-of-eight around one or preferably two teeth, either side of the fracture (must be firm). (b) Reduce fracture and tighten wire ends. Ensure wire is below maximum bulbosity of the teeth (in the cervical margin). (c) Wire tightened.

Indications for open treatment

When closed treatment is inappropriate or has failed. Closed treatment does not reduce fractures *anatomically* – it is wrong to assume that just because the teeth meet, the bone fragments are in the correct position. IMF does work, but is required for at least 4 weeks and has its own set of problems – and it is not without risk. Alternatively, open reduction and internal fixation (ORIF) may be undertaken. Both ORIF and IMF have advantages and disadvantages which should be carefully weighed and if possible discussed with the patient.

With 'ORIF', surgical exposure of the fracture site and (hopefully) anatomical reduction is carried out. There are two schools of thought:

1. Mandibular fractures need rigid fixation. Dynamic compression or rigid osteosynthesis offers this. However this requires an external approach (scar and risk to mandibular branch of facial nerve), (Figure 55.3) whilst bicortical screw fixation poses risks to dental roots and inferior alveolar nerve. A second procedure to remove the metalwork, later. The mandibular curvature makes this technically demanding and there are concerns about stress shielding. Nevertheless, this is reliable treatment and patients return to normal function quickly.
2. Mandibular fractures *do not* need *rigid* fixation. Studies have shown that 'micro movement' following 'semi rigid' fixation encourages callus formation and healing. Instead of large rigid plates, smaller ones are placed along well-defined 'zones of tension' arising at the fracture site (Figure 55.4), effectively converting them into 'zones of compression'. In selected cases, this can be done under local anaesthesia. For this fixation to work the periosteum needs to be mostly intact with good abutment of the fracture ends. Non compression, 'miniplates' can be placed transorally (or via an overlying laceration) and secured with monocortical screws, thereby avoiding some of the problems associated with the larger compression plates. Fine tuning of the bite is possible with elastic IMF and routine removal of the plates is not necessary. However, plates can occasionally get infected and patients still require a soft diet for the same period of time.

EXTERNAL FIXATION

This method of fixation should be regarded as 'open', even if the fracture is not accessed for inspection. It is used less frequently, but is a useful alternative to IMF (Figure 55.5):

1. In 'first-aid' stabilization prior to transfers.
2. To maintain space and fragment orientation in mandibular continuity defects (e.g. gunshot injuries).
3. In severely comminuted fractures.

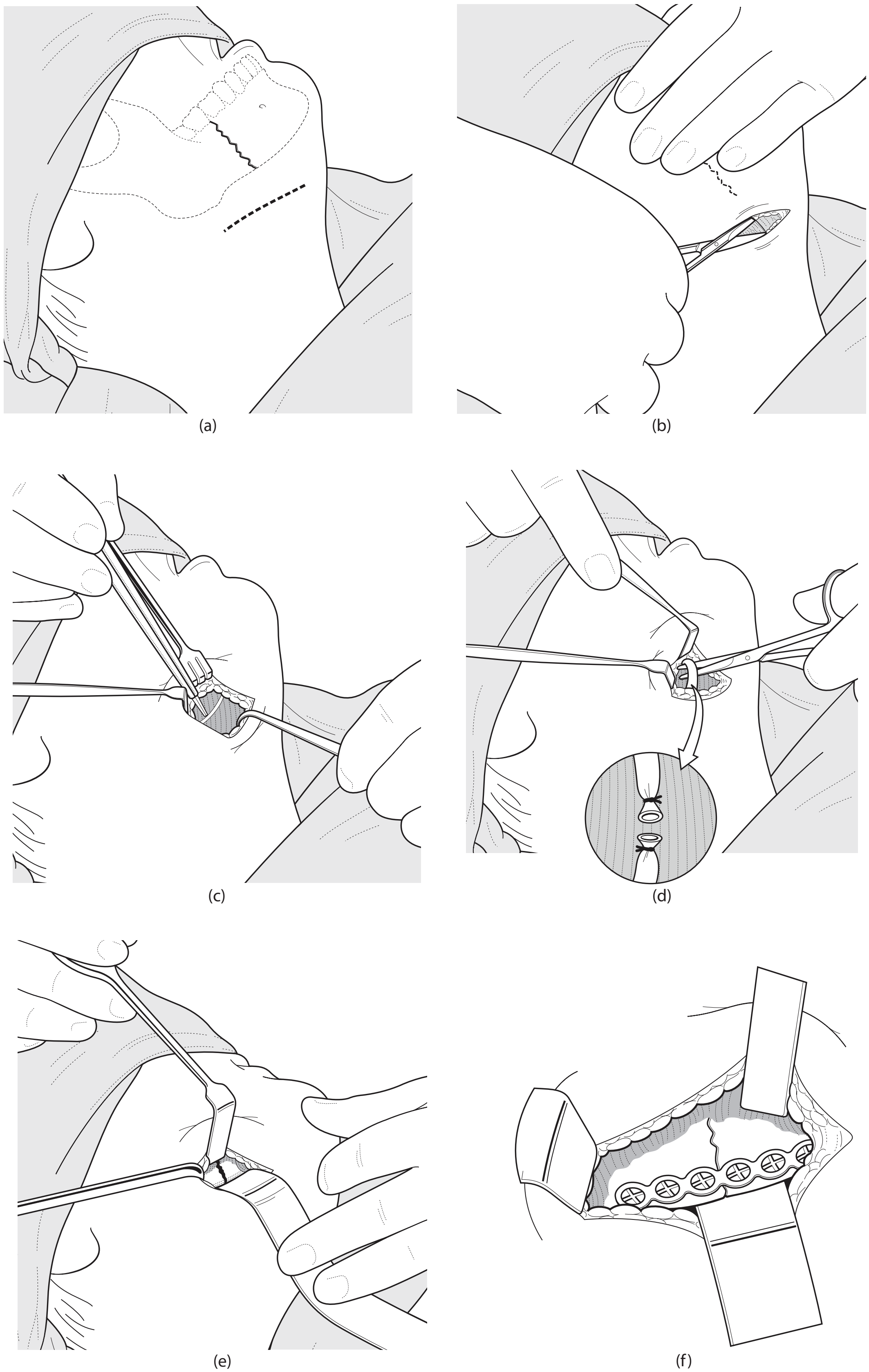


Figure 55.3 External approach to lower mandibular border. (a) Place skin incision in suitable crease (remember nerve anatomy). (b) Following incision, carefully deepen wound through platysma. (c) Watch out for the mandibular branch of VII (bipolar is showing nerve, not frying it!). (d) The facial vessels may need division and ligation. (e) Incise and lift periosteum to expose fracture. (f) Fracture repaired (this is not compression plating).

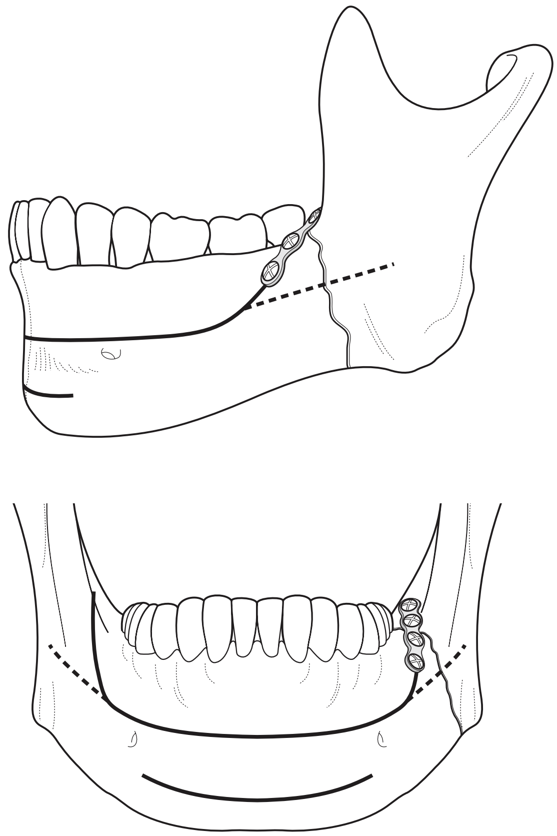


Figure 55.4 Champy's lines: zones of tension along which fixation plates may be secured.

4. In infected/contaminated fractures, at risk of spreading infection and/or osteomyelitis.

External fixation involves inserting rigid pins into the bone fragments via the skin, which are then joined by a system of joints and connecting rods. Fixation can be applied rapidly. Reduction is 'blind' although the fractures can be adjusted post-operatively. Pin insertion may damage the inferior dental nerve or teeth, patient activity is restricted and the pin sites may become infected with scarring. The frames are disliked by patients, and they can injure themselves.

SPECIFIC FRACTURES

Condyle fractures

This topic is covered elsewhere in this book.

Ramus fractures

These rarely need repair. The attached muscles of mastication effectively splint any fractures. If the occlusion is significantly disrupted elastic IMF may be applied.

Angle fractures

These may be partly splinted by the medial pterygoid and masseter muscles, but are often displaced and mobile. Fractures have been classified as vertically and horizontally favourable, or unfavourable, depending on the orientation of the fracture and tendency for it to displace by the pull of these muscles (Figure 55.6). This can occur when the periosteum has been ruptured or stripped from the bone allowing displacement to occur.

MINIPLATE PLACEMENT

Access can be made through a variety of incisions, sited along or lateral to the external oblique ridge. As a general principle, surgical wounds should not lay over any metalwork. Either an incision 'down-to-bone' or a two-layer approach may be used. The fracture is then manipulated, whilst re-establishing the occlusion (either by IMF or, if experienced 'hand-held') until it appears anatomically reduced. With simple fractures, a single-twisted (propeller) miniplate placed along the external oblique ridge (tension line) is usually sufficient in most cases. More recently, however, there has been interest in the placement of one or two plates, along the buccal surface of the reduced fracture. This approach requires drilling and screw placement via a transbuccal approach, whereby a trochar is passed through the cheek. Each approach has advantages and disadvantages and the final choice is a matter of surgical preference. Certainly in comminuted and very unstable fractures more than one plate may be necessary. In such cases, a limited external approach to enable lower mandibular border fixation may be required.

Symphyseal and parasymphyseal fractures

With symphyseal (midline) fractures the mylohyoid and geniohyoid muscles may help stabilize the fracture. However obliquely orientated fractures will tend to overlap. With bilateral parasymphyseal fractures the fragments can displace posteroinferiorly – so called 'bucket-handle' fractures. There are a number of approaches to the anterior mandible:

1. Gingival sulcus incision. Although relatively simple, if poorly closed can result in gingival recession.
2. Single layer incision at the junction of the attached and non-attached mucosa. This is also relatively simple, but requires a careful and watertight closure to reduce the likelihood of infection or dehiscence.
3. A two-layer incision placed in the sulcus. This is the authors' preferred approach. Very often the branches of the mental nerve can be seen through the mucosa and protected. A two-layer closure is also usually secure.

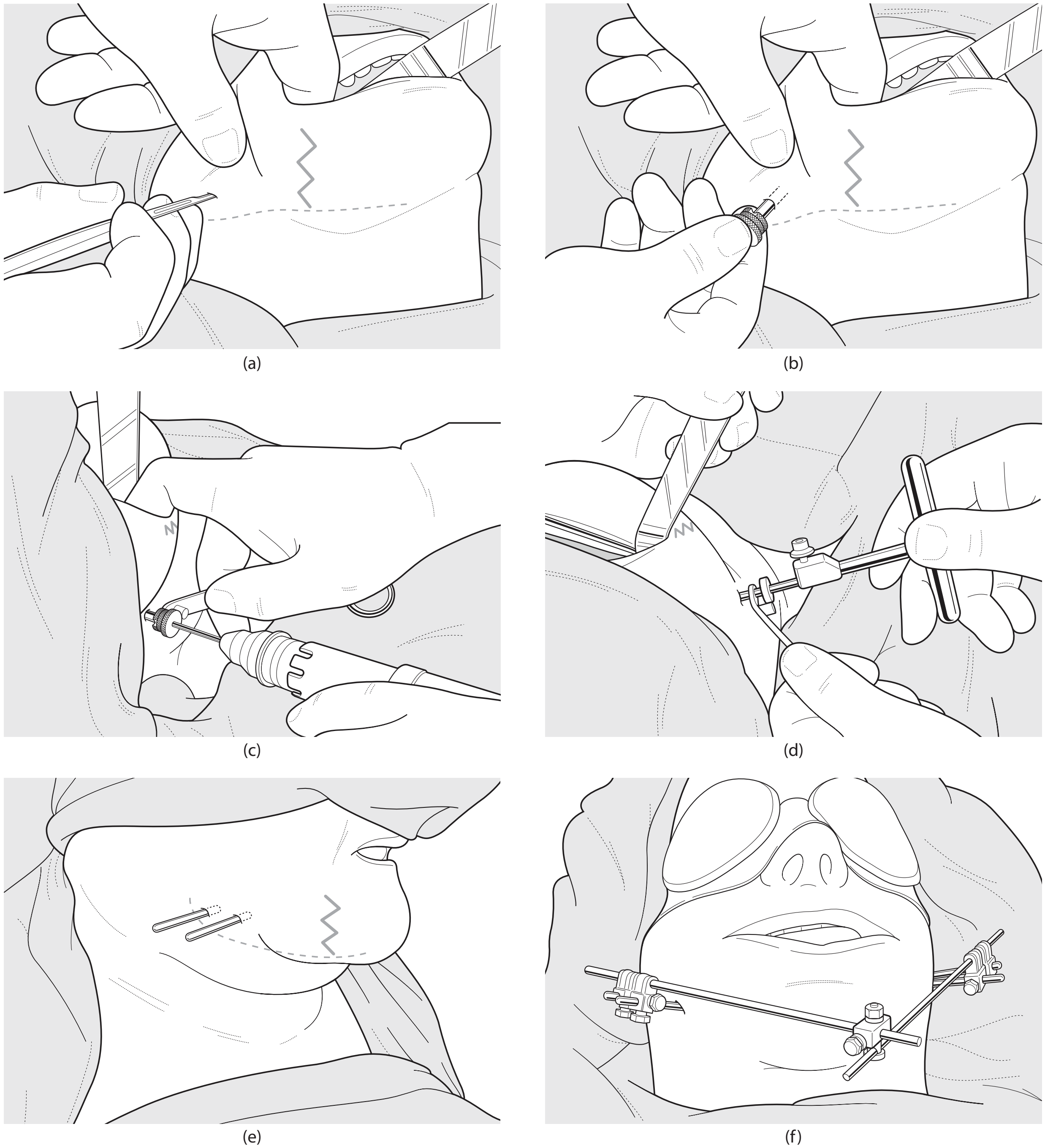


Figure 55.5 Expose fracture intra-orally to precisely define its site and extent. Then (a) stab incision for pin placement, (b) pass pointed trochar down to bone, (c) replace inner pointed trochar with drill guide and drill bicortical hole, (d) remove drill guide and place pin (depth gauge may be used), (e) repeat so that there are two pins either side of fracture, (f) completed arrangement.

4. Via any overlying lacerations. Even small ones should be considered – it is surprising how much access you can get once the deeper tissues have been mobilized.

With 'anterior' fractures (usually taken to mean those between the mental foramina), two miniplates are usually required to resist torsional forces following muscle pull. Place the lower miniplate along the thick lower border if possible. Care is required with drilling the upper miniplate (dental roots). In theory, holes can be drilled over the roots (monocortical screws), although in practice, many surgeons place the holes 5 mm or more below the apices, to avoid damage. This principle is often extended to the premolar region, and the number of plates used depends very much on the fracture configurations.

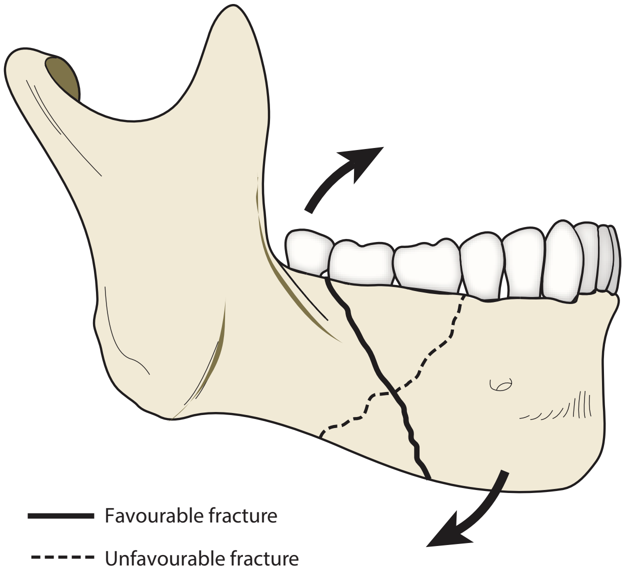


Figure 55.6 Favourable and unfavourable angle fractures (note: tendency to displace).

ANTIBIOTICS, STEROIDS AND TETANUS PROPHYLAXIS

Protocols may vary between different units. The use of pre-operative antibiotics has proven effective in reducing post-operative complications following repair of mandibular fractures. A fracture involving the periodontium of an erupted tooth should be considered an open fracture, requiring the administration of systemic antibiotics at least until the fracture has been reduced and immobilized. Penicillin (or a cephalosporin) and metronidazole is one option, but many exist. There has been much debate regarding the duration of antibiotics in the post-operative period. Studies, however, have shown no benefit for prolonged antibiotics (beyond post-operative day 1) in reducing the incidence of infections in uncomplicated mandibular fractures.

Tetanus prophylaxis should be considered especially in unclean wounds. Steroids (dexamethasone/methylprednisolone) are sometimes given in the perioperative phase to reduce facial swelling. Studies have shown that in healthy patients with clinically uninfected fractures there is no significantly increased risk of impaired wound healing associated with the prescription of perioperative steroids. The main factors associated with delayed or poor healing is being over 25 years of age and smoking.

SPECIAL CONSIDERATIONS

Tooth in the fracture site

Teeth in the line of a fractured mandible is a common problem. Canines and third molars in particular create points of weakness making fractures at these sites relatively common. Vital, functional or unerupted teeth can be left in situ as long as there is no associated pathology with the tooth. The concern is with retained non-vital or periodontally involved teeth which may encourage infection in the fracture resulting in non-union or abscess formation. The indications for tooth removal are as follows:

1. The tooth interferes with fracture reduction.
2. The tooth is fractured. Devitalized roots act as a nidus for infection.
3. Tooth with advanced dental caries.
4. Tooth with established periodontal disease.
5. The presence of associated pathology such as cysts or pericoronitis.

If the tooth is elevated, precise reduction and immobilization of the fracture can be difficult particularly if bone has been removed in the process. For this reason, if the tooth has to be removed, it is sometimes easier to plate the fracture first, then remove the plate before elevating the tooth.

Fractures in children

Children have ‘bendy’ bones compared with adults. A fracture anywhere in the body implies relatively more force than in an adult (especially ribs). Mandibular fractures are unusual as the facial skeleton is less prominent. Any minor occlusal changes are usually compensated for with growth and repair is less common. Resorbable plates are often used.

Edentulous fractures

The severely atrophic edentulous mandible often has a poor outcome especially when the height of the mandible is 10 mm or less. These are characterized by poor blood supply and slow healing, especially in patients with poor general health and osteoporotic bones. IMF is not possible (no teeth) and any periosteal stripping jeopardizes the blood supply. A direct relationship between the height of the bone in the fractured area and the incidence of complications has been reported. A non-union or fibrous union is more likely to occur when the height of the mandible is less than 10 mm. The treatment options for the fractured edentulous mandible are as follows:

1. Soft diet and regular review to allow a fibrous union. This is an appropriate option in frail patients and those with minimally displaced closed fractures. This option avoids the need for surgery. If necessary, the patient’s dentures can be relined to improve the fit.
2. Closed reduction using the patient’s dentures (if a good fit) or customized ‘gunning splints’, to the maxilla and mandible to allow IMF. Patient selection is important

(respiratory diseases, etc.) as a general anaesthetic is required to wire the splints and longer periods of IMF maybe required.
3. External fixation. Used in cases where there are major concerns about healing (e.g. infected wounds), or highly comminuted fractures.
4. Internal fixation using miniplates. Usually effective in simple fractures providing the height of the mandible is above 20 mm.
5. Internal fixation using heavier reconstruction plates. Appropriate for comminuted fractures particularly if the height of the mandible is less than 20 mm.

However, the 2007 Cochrane database review failed to show a better outcome regarding the management of edentulous fractures with any single approach over the other alternatives. Treatment must, therefore, be considered on a case by case basis with very close follow-up.

POST-OPERATIVE CARE

- Genioplasty dressing to prevent chin ptosis following extensive anterior exposure (optional).
- Antibiotics – no benefit in continuing antibiotics beyond day 1 post-op in non-complicated fractures.
- Post-operative radiographs may be taken to confirm good repair.
- Soft diet and nutritional advice for 4–6 weeks.
- Oral hygiene is very important. Tooth brushing and chlorhexidine mouth rinses are the main element.
- Regular follow-up for 6 weeks.

Top tips

- Fractures of the mandible in restrained supine patients is not a good mix. Never leave such patients unattended.
- Comminution implies high energy and the risk of significant airway swelling.
- Check the hyoid and larynx for associated injuries.
- Beware patients who repeatedly ask to sit up – this may indicate airway difficulties.
- Vomiting is best managed by tilting the trolley head down, rather than attempting to log roll the patient.
- Mental parasthesia is both an important diagnostic sign and an important medico-legal observation prior to treatment.
- Missing teeth must be accounted for. Both a chest x-ray and soft-tissue view of the neck may be required.
- A sublingual haematoma is pathognomonic of a mandibular fracture and may also compromise the airway.
- The mandible commonly fractures in two places – if you see one fracture look for another (cf. pelvic fractures).
- Unerupted wisdom teeth can rotate in their sockets and displace angle fractures enough to affect the occlusion.
- If removing an associated tooth, plate the fracture first, take the plate off and remove the tooth. This can help in unstable fractures.

56

Management of condylar fractures including endoscopic reduction

ROGER CURRIE

CONTENTS

INTRODUCTION

Condylar fractures are an important subgroup of mandibular fractures both in presentation and management. Fractures may present in isolation or in conjunction with other mandibular fractures, or as a component of a panfacial injury. The age of the patient is also an important factor in the management of this subgroup of fractures. Various issues have challenged the management of condylar fractures, which include a variety of classifications, concern in relation to surgical access and the limitations of technology. The contemporary management of condylar fractures exemplifies the advances in technology and surgical access that the last decade has seen in oral and maxillofacial surgery.

INCIDENCE AND CLASSIFICATION

The literature has various figures for the incidence of condylar fractures from 30% to 50% of all mandibular fractures; the commonest cause of presentation in the United Kingdom is a result of interpersonal violence, with at least 50% of patients having an associated mandibular fracture. Over 80% of fractures are unilateral, with the highest incidence in the age range of 20–39 with at least a 2:1 sex ratio (male:female).

Classification of condylar injuries has been difficult. This is in part due to the types of classification in use. These may relate to anatomical position, i.e. condylar neck or may relate to displacement of the condylar fragment. Previously classifications have included Speissl and Schroll, MacLennan and Lindahl. In 2005 as part of the Strasbourg Osteosynthesis Research Group (SORG) study, Loukota et al.[1] published a sub-classification of condylar fractures which is both pragmatic and clinically useful as it aids visualization and consideration of treatment options when combined with degree of overlap (in mm) and angle of displacement.

DEFINITIONS

1. Diacapitular (through the head of the condyle) fracture; the fracture starts in the articular surface and may extend outside the capsule.

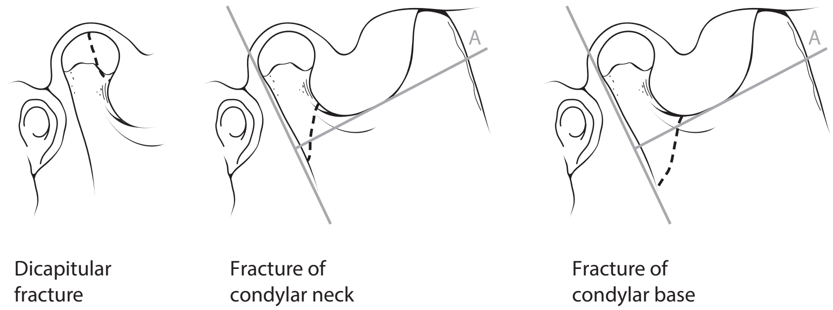


Figure 56.1 Classification of condylar fractures. (Modified from Loukota, R.A. et al. *Br J Oral Maxillofac Surg*., 43, 72–73, 2005.)

2. Fracture of the condylar neck. The fracture line starts above line A, and in more than half the fracture distance runs *above* line A. High condylar fracture.
3. Fracture of the condylar base. The fracture line runs behind the mandibular foramen and in more than half the distance *below* line A. Low condylar fracture.
4. Line A. A perpendicular line through the sigmoid notch tangential to the ascending ramus (Figure 56.1).

INVESTIGATIONS AND IMAGING

A good history and clinical examination will be required as for all trauma patients. Condylar fractures may well be discovered in the 'secondary survey', as in Advanced Trauma Life Support (ATLS) protocols.

Clinical signs include pain, limited mouth opening, deviation on opening, lateral or anterior open bites, chin or external auditory meatus lacerations.

The mechanism of injury, associated injuries and the clinical findings will direct the imaging required.

Imaging in two planes is the normal investigation, usually an orthopantomogram (OPT) and posterioanterior (PA) mandible. With the advent of spiral computed tomography (CT) scanning, some surgeons may have a CT as an initial investigation. A CT may well be helpful with bilateral fractures, gross medial displacement and impacted fractures where a contralateral open bite is present due to the 'crushing' of the condylar head. Cone beam computed tomography (CBCT) is a new addition to the available imaging options and may be useful in both diagnosis and follow-up.

TREATMENT OPTIONS AND OUTCOMES

- No treatment
- Closed reduction
- Open reduction
- Endoscopically assisted
- Free plating and grafting

The commonest clinical scenario is the management of the unilateral condylar fracture, with or without another mandibular fracture. Debate over this has been intense over the last decade with two consensus conferences and a recent prospective randomized multi-centre study. In 1993, only 9% of the surgeons questioned would consider open reduction internal fixation (ORIF). Whilst opinion is still divided, more evidence supports open reduction in defined clinical circumstances.

Patient specific variables also impact on treatment decisions: age, ability to cooperate; other facial fractures and comorbidity all influence the management decision (Table 56.1).

Surgical variables include experience, fracture location (and imaging) and available instruments, e.g. endoscopy.

Table 56.1 Ideal outcomes of condylar fracture treatment.

Outcome
Pain-free mouth opening >40 mm
Pain-free lateral excursions >6 mm
Stable and pain-free occlusion
Normal facial and jaw symmetry

Table 56.2 Indications for closed management.

Indications
Condylar neck fractures in children <15 years
Very high condylar neck fractures without dislocation
Intra-capsular fractures

No treatment

When no occlusal discrepancy or functional impairment exists.

Closed reduction (management)

This is a blanket term, which implies no 'open' intervention (Table 56.2). In common practice, it would involve the placement of arch bars, splints, IMF screws or rapid IMF™. All of these allow the placement of elastic intermaxillary traction/inter-maxillary fixation (IMF).

The precise post-operative course can vary from 2 weeks to 3 months using guiding elastics, with most surgeons using elastics for 2–4 weeks. It is now well accepted that there is no place for rigid IMF.

Closed management was the previous treatment of choice for both displaced and non-displaced fractures. Many surgeons had concerns about damage to the facial nerve with open reduction and it was not clear that surgically reduced fractures gave better results. Complications of closed management can include painful or limited opening, deviation on opening, malocclusion and loss of posterior facial height. Outcome studies performed by Ellis confirm malocclusion, occlusal canting and loss of posterior facial height in patients treated with closed management compared to open reduction. The facial asymmetry was notable at 6 weeks.

Open reduction

Open reduction is not a new concept having been proposed in certain defined circumstances by Zide and Kent in 1983.[2] The impact of technology as stated in Table 56.3 and the increased understanding of both the biomechanical and functional advantages of plating supported by good randomized studies have encouraged surgeons to revaluate open reduction, and for others to explore endoscopically assisted reduction.

The principles of open management are similar for all fractures and include accurate reduction, stable internal fixation, preservation of blood supply and early active mobilization.

With open reduction of condylar fractures, the main specific concerns are facial nerve weakness/paralysis and scarring.

Much work has been carried out on evaluating open reduction (Table 56.4) and various surgical approaches have been described including submandibular, retromandibular with trans-parotid access, pre-auricular, coronal and rhytidectomy. If midfacial access is required then a coronal approach may well be helpful; however, for the majority of cases a retromandibular incision parallel to the posterior border of the mandible with trans-parotid dissection will allow safe exposure of the fracture. However, no trial evidence exists comparing the various access approaches, these can be broadly considered as either deep to or transversing the course of the facial nerve.

Materials used for fixation include, transosseous wires, K wire, screws and plates. The commonest method of fixation is 2.0 mm titanium semi-rigid plates. Asprino et al.'s[3] biomechanical evaluation included one or two 2 mm plates with 4, 6 or 8 mm screws. The most favourable mechanical behaviour was with two-plate fixation, although increasing screw length improved stability if only one thicker plate was used. Current evidence supports the use of two plates or specifically designed three-dimensional plates with 8 or 6 mm screws.

A 70% success rate has been reported by Davis et al.[4] with free grafting alone or in conjunction with a ramus osteotomy in cases when adequate reduction and fixation could not be obtained.

Table 56.3 Impact of technology.

New technologies	
Plates	
Imaging	
Instruments	Endoscope
	90° screwdriver

Table 56.4 Indications for open reduction include.

Indications
Fracture dislocation angulation of >30°
Need to establish posterior facial height loss of >5 mm
Failed closed management
Displacement into middle cranial fossa or external auditory meatus
Bilateral condylar fractures with associated panfacial fractures
Medical contraindication to inter-maxillary fixation (IMF), e.g. epilepsy

MANAGEMENT OF ISOLATED UNILATERAL CONDYLAR FRACTURE

Informed consent must be obtained including discussion of likely complications including scarring and facial nerve damage, though longer term studies by Downie et al.[5] provide good evidence that permanent damage is rare.

Under endotracheal general anaesthesia the patient is prepped and draped, allowing access to the oral cavity for downward distraction of the ipsilateral angle to aid reduction. An intravenous dose of antibiotic is given at induction. Ideally, two assistants are required for retraction and mandibular manipulation. A small plug is placed in the external auditory meatus. The retromandibular incision is marked 1 cm distal to the posterior border of the ramus, approximately 2 cm in length (Figure 56.2).

Figure 56.2 Retromandibular (trans-parotid) incision.

Wide dissection in the superficial layer above the parotid fascia is carried out to facilitate retraction. The parotid fascia is divided sharply and with blunt dissection under direct vision the facial nerve branches if encountered are retracted out of the operative field. Once the masseter muscle is exposed, the surgeon uses a finger to palpate the underlying fracture and a vertical incision is made down to bone. Sub-periosteal stripping exposes the fracture though the condylar fracture can be 'trapped' in the muscle and then requires careful dissection.

With retraction in a superior/inferior direction and use of a thin-bladed retractor behind the posterior border, the mandible can be displaced downwards and backwards with occlusal pressure, which increases the space and aids fracture reduction. Once fracture reduction has been achieved, adequate fixation is required. Some surgeons use intra-operative IMF, others will handhold the occlusion whilst it is fixed.

Options for plate fixation include one 2-mm dynamic compression plate (DCP) plate or two 2-mm plates placed as far apart as possible. Newer shaped plates may offer some ease of application. It is important to insert at least two screws (6–8 mm) in the distal aspect of the proximal fracture. Placing the superior screw without the mandible in occlusion then re-reducing the fracture and placing the second screw, prior to fixation of the distal fragment, can facilitate this. A fracture gap can open at this point and a two holes–spaced plate with the space over the fracture is useful to close this gap by placing the superior screw and then securing manual reduction of occlusion with inferior traction on the distal screw holes of both plates to close the fracture gap prior to placing the final three screws (Figure 56.3).

The wound is closed in layers with attention to closing the masseter muscle and the parotid fascia/superficial musculoaponeurotic system (SMAS) prior to skin closure with non-resorbable sutures.

In 2009, using this technique 50 patients were reported by Downie et al.[4] No patients had permanent facial weakness, seven patients had transient facial weakness most commonly the buccal branch with a mean recovery of 4 months, two sialoceles which settled with time, a wound infection and a plate failure, which did not impact on the clinical result (Figures 56.4 through 56.6).

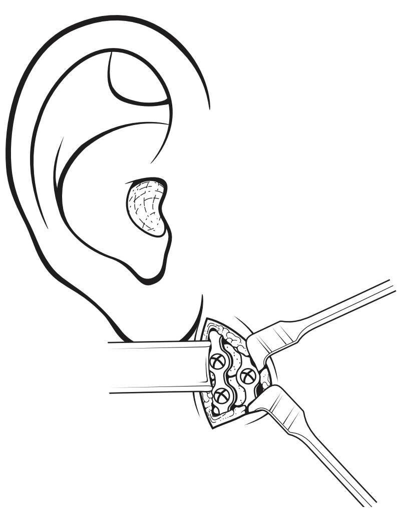


Figure 56.3 Fracture exposed and reduced.

Endoscopically assisted reduction of condylar fractures

Although open reduction became more accepted, groups of surgeons have looked at using newer technology and applying this within maxillofacial surgery. Endoscopically assisted reduction is a good example, as it reduces the risk to the facial nerve and minimizes scarring. Work done on the development of this technique confirms that there is a long

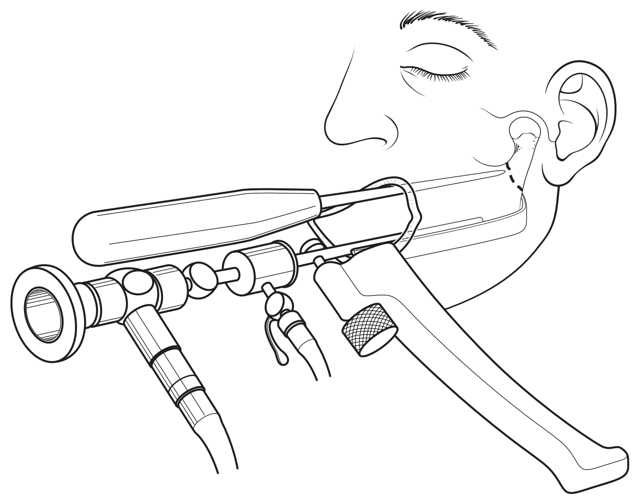


Figure 56.4 Endoscopic principles.

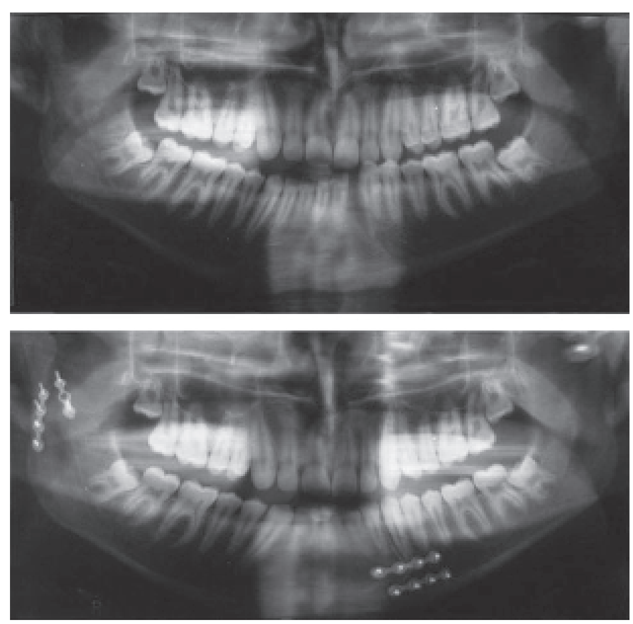


Figure 56.5 Combined pre- and post-operative orthopantomograms (OPTs).

Figure 56.6 Pre-operative posteroanterior (PA) mandible radiograph.

and steep learning curve and that laterally displaced fractures are much easier than medially displaced fractures; like all endoscopic procedures, surgeons must be able to convert to an open procedure to complete the surgery if needed.

With this, development plating companies have designed and produced special instruments to facilitate endoscopically assisted reduction; however, most institutions have only the basic light sources, monitor banks and camera attachments.

The endoscopic approach uses an intra-oral approach or a submandibular approach along with a trans-buccal access for some fixation.

Using the intra-oral approach, a ramus incision similar to one for a mandibular osteotomy is made and the masseter muscle stripped to create the optical cavity. A 4 mm 30° endoscope with an adapted retractor provides direct vision and this is aided by a Freer elevator with built in suction. Under vision and with special instruments the fracture is manipulated and reduced, this may require extensive dissection at the posterior border or the sigmoid notch. Occasionally downward traction may be needed, this can be digital occlusal pressure or a wire at the angle.

The transoral approach can be used to place screws using an adaptable plate holder or a 90° screwdriver can be used though this can be difficult in a tight soft-tissue envelope. Occasionally a second trans-buccal stab may be needed to use a threaded fracture manipulator 'the screw on a stick', which can be used to place the initial screw in the proximal fragment.

In 2006, Muller et al.[6] reported results of 150 fractures, where treatment times were down to 70 minutes, and 91% obtaining primary plate fixation. Unfortunately, 9% were aborted and required either open or closed management

Figure 56.7 Post-operative PA mandible radiograph.

and fewer than 2% developing plate fracture or transient facial nerve weakness.

Modifications of this approach repeated in 2011 with transoral access with a 90° screwdriver and drill have given equivalent results but with mean treatment times of 50 minutes.

Further refinement of all these techniques will be required as challenges exist with difficulty reducing medially displaced fractures, a limited surgical cavity compared to other endoscopic procedures, the need for special training and instrumentation, and the reduction of morbidity and treatment time (Figure 56.7).

PAEDIATRIC FRACTURES

Children with condylar fractures are a very different group. Children exhibit a regenerative capacity that adults do not and will regenerate condylar form and function whilst adults compensate at an occlusal level with loss of posterior facial height.

In 2005, Dodson[7] reviewed paediatric condyle/ramus fractures and reported good outcomes; however, increasing age was associated with poorer outcomes. These younger patients often require long-term follow-up as they can in rare circumstances present in later years with developmental abnormalities including asymmetry, condylar head resorption or ankylosis.

PANFACIAL FRACTURES

One of the clear indications for open reduction of condylar fractures is an associated midfacial fracture. The correction of vertical height aids the correction of the midfacial deformity and should be carried out when the mandibular fractures are reduced, perhaps before definitive midface correction.

BILATERAL FRACTURES

When associated with a symphyseal fracture this can lead to mandibular widening and great care must be taken to ensure accurate reduction at the symphysis or a post-operative malocclusion will be evident, in spite of anatomical condylar fracture reductions.

If two fractures are present it is ideal to fix both; however, at least one needs to be fixed to regain facial height.

POST-OPERATIVE MANAGEMENT

Good post-operative care with elastic traction for closed management and jaw exercises and clear post-operative instructions for open or endoscopic treated fractures are needed.

COMPLICATIONS

- Malocclusion
- Condylar necrosis, with associated open bite
- Wound infection (rare <1%)
- Hypertrophic scarring
- Facial nerve weakness, transient or permanent
- Sialocele
- Fixation failure

Top tips

- Treat the patient and the occlusion, not the radiograph.
- Ensure you have adequate assistance.
- Start with easier low laterally displaced fractures when starting open reductions.
- Do not attempt a high medially placed fracture as your first.
- Give clear post-operative instructions.
- Consider endoscopic approaches only when you have mastered open surgery.
- Use new technology to aid treatment, e.g. three-dimensional plates.

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57

Middle third fractures

JOE MCMANNERS, JEREMY MCMAHON and IAN HOLLAND

CONTENTS

DIAGNOSIS

The essential basic history, examination and directed special tests are the same as for any injured patient (see Chapter 51). Particular care in clinical examination should be sufficient to make most diagnoses of middle third fractures (see the section 'Classification').

Special tests

Plain radiography has a limited place in the diagnosis and treatment planning, as illustrated (Figure 57.1). Computed tomography (CT) scanning has enabled greatly improved visualization of the nature of the midface injury, which is usually much more complex than has previously been realized (Figures 57.2 and 57.3). Having said that, all that is revealed by a scan does not necessarily need internal fixation. Dental models from impressions taken once the patient is stabilized may be very helpful in diagnosing and restoring the occlusion at operation. Other imaging modalities may be necessary when indicated, e.g. contrast arteriography.

CLASSIFICATION

Midface fractures are often classified as central midface and lateral midface or zygomatico-orbital fractures.

Central midface fractures

- Low level, just above the tooth-bearing maxilla and alveolar process: Le Fort I (Figure 57.4a through d).
- Midface, involving the inferior orbital margins and nasal complex (pyramidal): Le Fort II (Figure 57.5a through d).
- High level, involving the arch of the zygoma, lateral, floor and medial orbit and root of the nose/frontal sinus: Le Fort III (Figure 57.6a through d).

Naso-orbital ethmoidal injuries

Naso-orbital ethmoidal (NOE) injuries are central midface fractures forming an integral part of the higher level injuries: Le Fort II and III fractures. NOE fracture management may be particularly complex and is dealt with in Chapter 59.

USING EXAMINATION WITH CLASSIFICATION

Examination identifies and differentiates between these levels. This may be difficult and academic as 'imperfect' fracture lines often mean asymmetry, as well as impossible subclassifications (for example, is there a unilateral Le Fort III or a Le Fort I associated with a same side zygomatico-orbital complex fracture?).

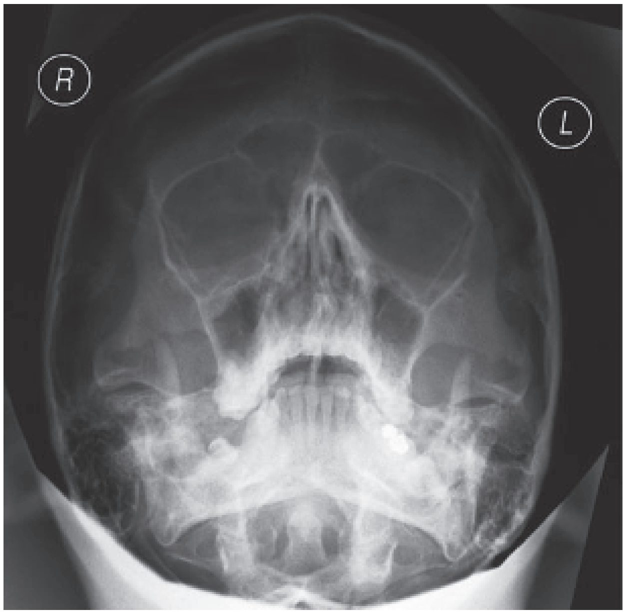

Figure 57.1 Occipito mental (OM) view of injury (not showing any obvious fracture).

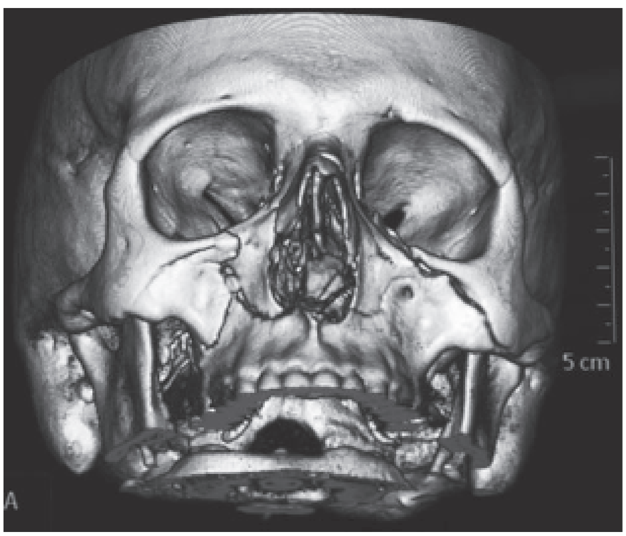

Figure 57.2 Three dimensional computed tomography (3D CT) showing Le Fort II and I fractures.

Look in particular for bruising, lacerations and loss of facial contour around the orbits and midface. This may be difficult to see because of swelling (balloon facies) disguising the underlying facial contour. Gentle palpation may be helpful around the orbits. Bilateral 'panda eyes' (indicating fractures within the orbit or base of skull), nasal deformities and lengthening of the face (the maxilla is often driven down and back) may also be seen.

Le Fort I

An isolated fracture may cause minimal facial deformity (Figures 57.7 and 57.8). Most higher level fractures

Figure 57.3 3D CT showing Le Fort II and I fractures.

will have a Le Fort I component (see under the section 'Treatment'). There may be lengthening of the face associated with the maxilla being driven down and back. Oral examination may reveal mobility of the whole maxillary dentition: dentoalveolar fractures may lead to more localized areas of mobility, split palate can give a traumatic central diastema and palpation of the zygomatic buttress may reveal irregularities from the fractures. An impacted, immobile maxillary fracture may exhibit a dull note when tapping the teeth ('cracked cup sign').

Le Fort II

Isolated fractures are rare and these injuries are often associated with other maxillary fractures and fractures of the surrounding structures. The illustrated case does not have a significant NOE component; however, this should be assessed over time if there is significant swelling, as any functional problem or deformity may be disguised. Issues, such as medial canthal ligament attachment (tested using the draw sign – palpation of the tensed ligament), orbital involvement, e.g. a palpable step in the orbital rim or eye movement problems giving double vision, frontal sinus fracture (usually confirmed and assessed using imaging) and nasal disruption, should be addressed.

Le Fort III

Le Fort III fractures present a similar picture with even more chance of significant involvement of the

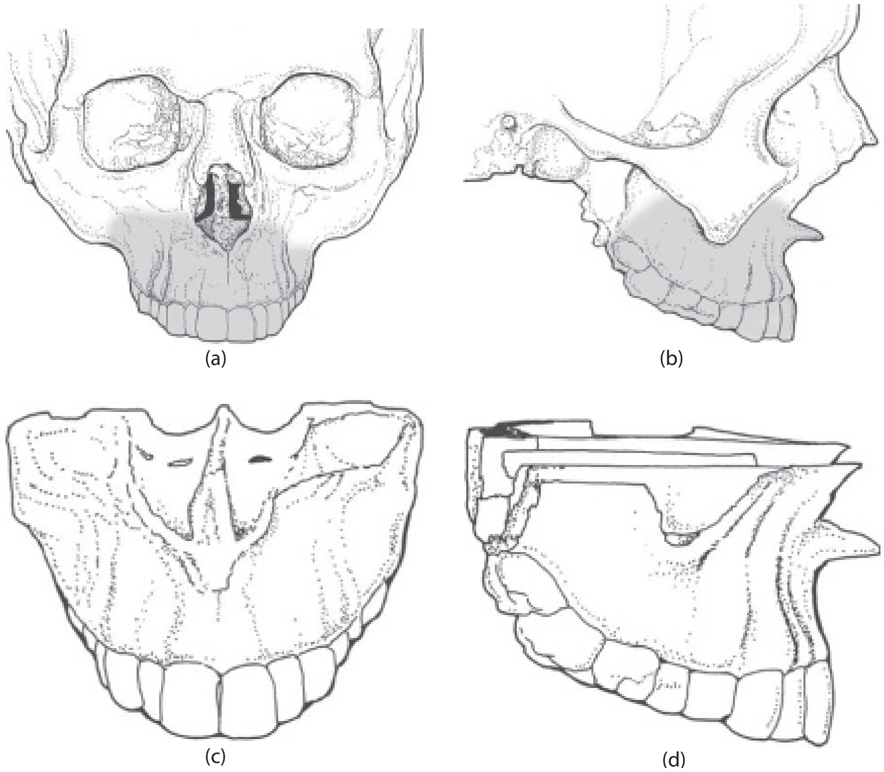

Figure 57.4 (a–d) Le Fort I.

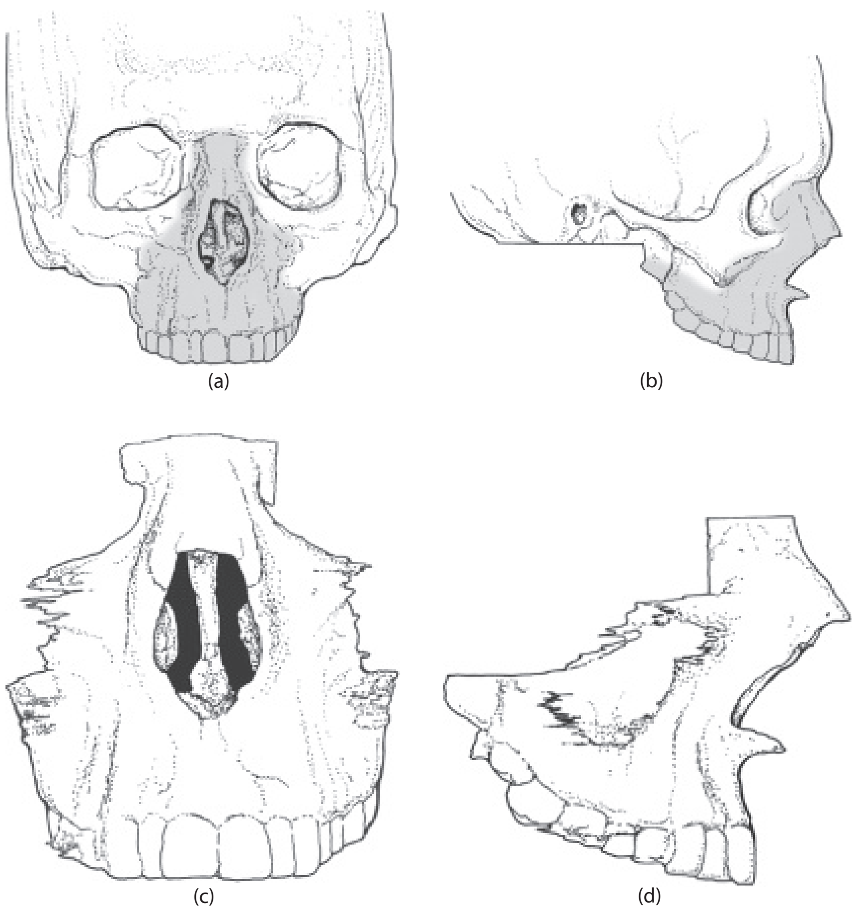

Figure 57.5 (a–d) Le Fort II.

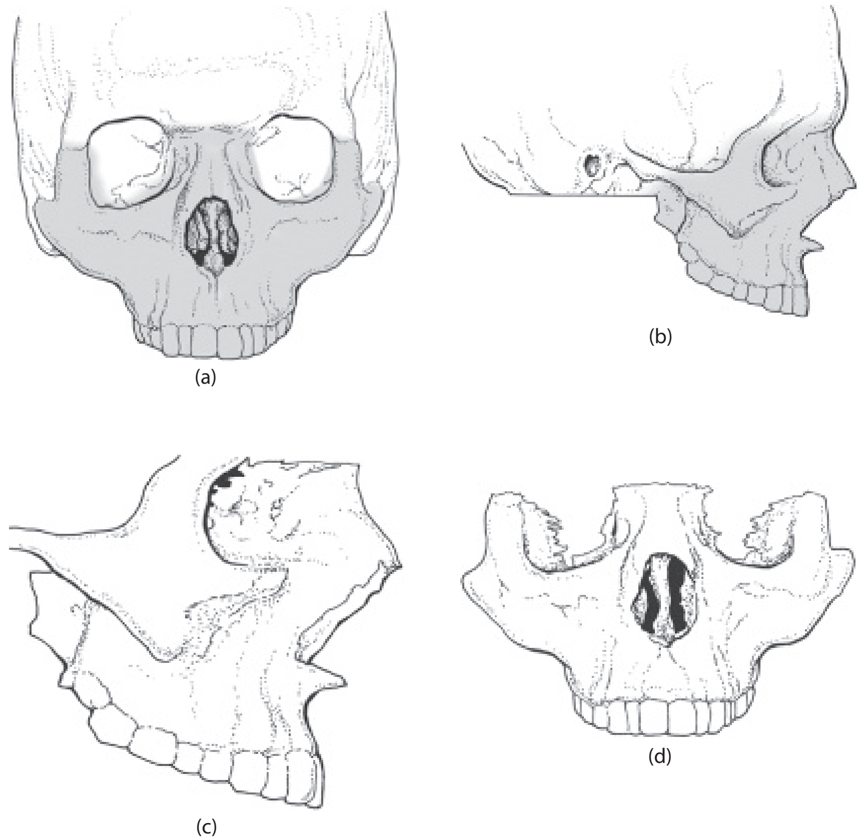

Figure 57.6 (a–d) Le Fort III.

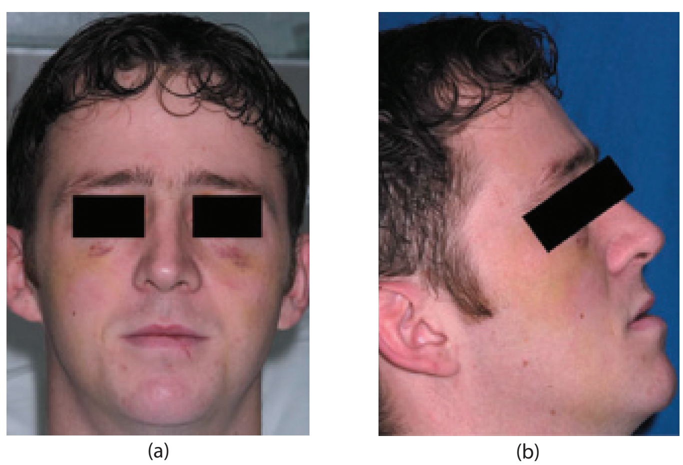

Figure 57.7 (a and b) Anteroposterior (AP) and lateral views showing no significant clinical naso-orbital ethmoidal injury or maxillary deformity.

surrounding structures. The main concern is of cranial involvement and scanning is mandatory. The higher level fractures both have the capability for increasing the width of the facial skeleton, as well as anteroposterior and height issues. This dimension is easily overlooked in planning the treatment of the grossly swollen face.

The authors hope it is clear that the more complex higher level injuries will need assessment and treatment of the surrounding structures.

Figure 57.8 Anterior open-bite deformity.

As well as the frontal sinus and base of skull already mentioned, the assessment of the NOE complex, the orbit and the zygomatic orbital complex need to be looked at in detail.

OTHER FACTORS

High- or low-velocity impact

High- or low-velocity impact will determine the likelihood of significant other injuries and the possibility of bone loss and the need for grafting.

Extremes of age

Older patients often have very thin bone, particularly when edentulous. This may have particular relevance when determining what kind of fixation to use and whether more simple 'closed' methods should be contemplated. Young patients may not have fully formed sinuses and exhibit unusual patterns of injury. The child's maxilla will be full of developing teeth, again posing potential problems for the use of internal fixation.

SURGICAL ANATOMY

Gruss and Mackinnon made an important conceptual advance in the mid-1980s describing the vertical supportive pillars of the midface: anteromedially the paired frontonasal maxillary pillars, laterally the zygomaticomaxillary pillars and posteriorly the pterygoid processes. In individuals with fully developed sinuses, these pillars are relatively weak in the midface. Unfortunately, for those repairing midface fractures, the most robust of these supportive pillars, the pterygoid plates (in fact, muscular processes) are inaccessible for direct operative repair. Subsequently, horizontal facial buttresses have been added: superiorly, the frontal bar of the upper facial subunit, inferiorly, the maxillary alveolus and palatal processes, with a contribution from the horizontal process of the palatine bone. The middle horizontal buttress is composed of the zygomatic arches, body of the zygomatic bones and the infraorbital rim. These transversely orientated supportive elements link the zygomaticomaxillary processes and nasomaxillary processes.

There are many issues with regards to the facial soft tissues and the effects of trauma, as well as wide undermining to access fractures. A feature of severe midface trauma is an appearance that suggests premature ageing when patients are reviewed later. This may be related to the changes within the soft-tissue facial drape as a consequence of severe contusion. However, where wide access is employed, the entire superficial muscular aponeurotic system (SMAS) retaining adhesions and septa are detached. Soft-tissue resuspension must therefore be part of any successful operative strategy.

PLANNING TREATMENT

The condition of the patient and their other injuries will be considered first. The authors work in a unit that delays treatment until brain swelling has had time to settle (usually 7–10 days). Only interventions that are absolutely necessary (for example, laparotomy, limb fracture stabilization and mandible fracture open reduction and internal fixation [ORIF]) are carried out earlier.

Operative planning for the facial injuries is facilitated with elective scans, involvement of other specialties (for example, neurosurgery, ophthalmology, otorhinolaryngology and maxillofacial technicians), use of dental casts and even photographs of the patients face prior to the trauma.

The management of the airway, if not already dealt with by tracheostomy, is a major issue. There are other methods of securing the airway, e.g. submental intubation; however, these issues need specialist planning. More simple fractures may be dealt with by nasal intubation. An experienced anaesthetist is needed when significant nasal disruption is present. In this type of case, a change of tube to an oral intubation may be necessary once the maxilla is fixed internally, in order to deal with the nose.

Often midface fractures are present with multiple other facial and skull injuries. The definitive intervention is best planned meticulously, as several specialties may be involved. Sequencing of the various parts of the reduction and fixation are very important when dealing with multiple fracture levels (see a suggested sequence in Figures 57.9 through 57.15).

The upper facial half can be divided into an upper unit (comprising the frontal bone and a maxillofacial unit). The lower facial half is subdivided into an occlusal unit and a lower basal unit.

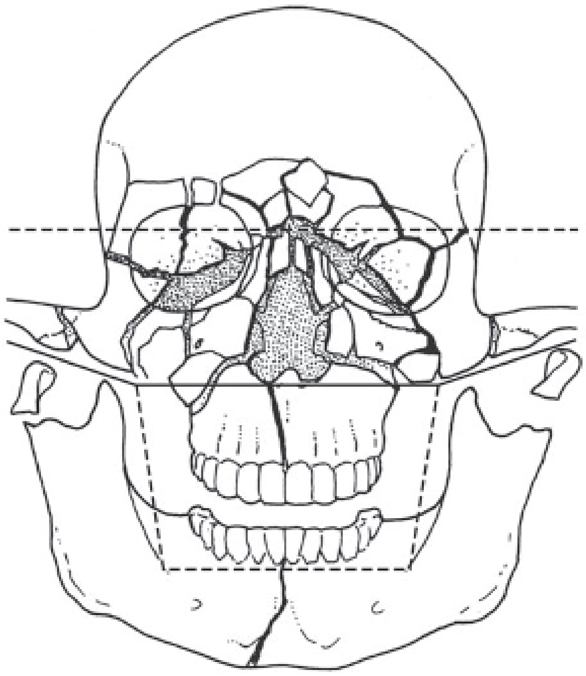

Figure 57.9 A useful way of looking at panfacial fractures is to divide them into two facial halves separated by a fracture at the Le Fort I level.

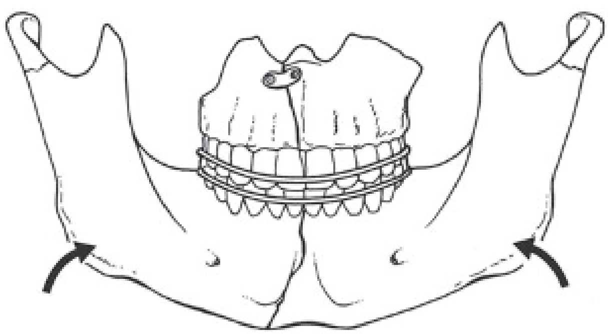

Figure 57.10 We suggest establishing facial width at the occlusal level first in order to deal with the sagittal element of maxilla and mandible fractures.

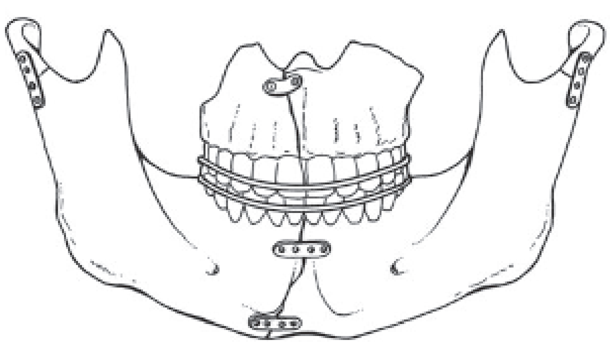

Figure 57.11 This is a good point to fix the condyles in order to finalize width issues and help with establishing posterior height (do not forget that the condyle may be accessible from the bicoronal flap approach).

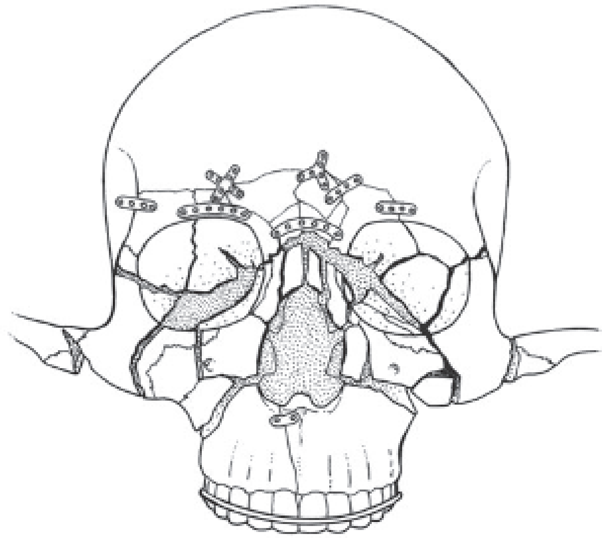

Figure 57.12 Next in our suggested sequence is the reassembly of the craniofacial/upper facial subunit.

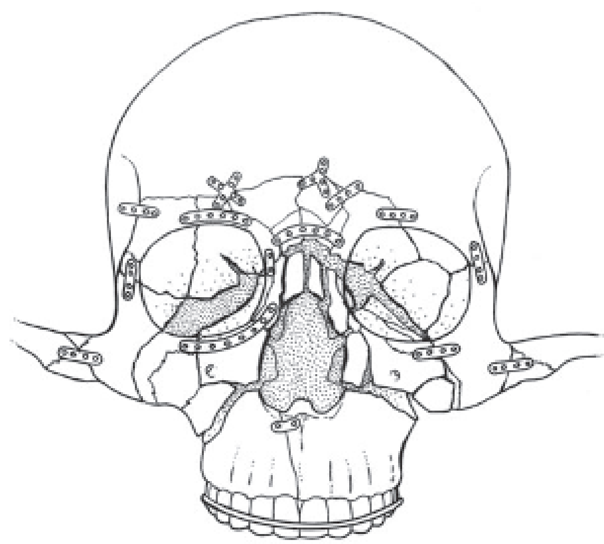

Figure 57.13 The midface repair should begin at the area of least displacement so as to give the best chance of getting the correct AP projection and width in this region. The arch of the zygoma is straight, not curved.

The gross manipulation of the facial skeleton using the Rowe's disimpaction forceps needs to be completed before any fixation is applied. If the neurosurgeons are involved with anterior fossa repair, the reduction may be done under direct vision to minimize disruption.

When starting this part of the reduction, pressure at the gonial angles will reduce the splay until the anterior mandibular fracture begins to open. This is the moment to stop any further pressure on the reduction and apply the plates.

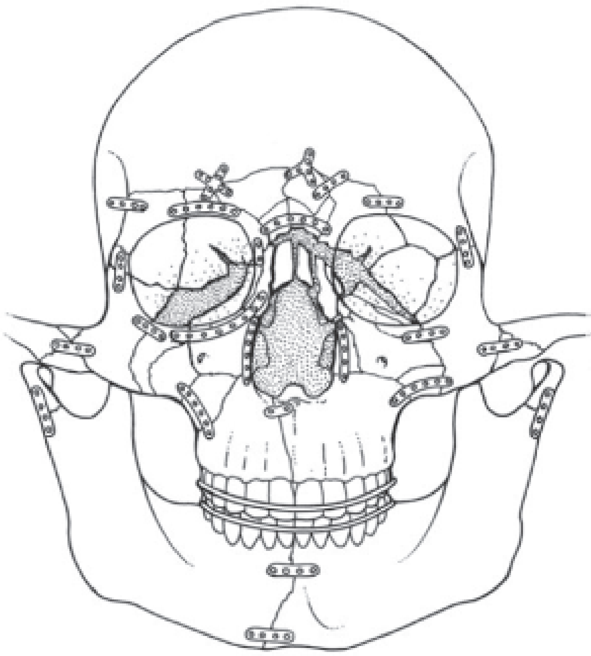

Figure 57.14 Finally the piriform fossa and zygomatic buttress plating is performed. The area of thin bone in between the buttresses can be severely comminuted. Occasionally in the high-velocity injuries the buttress areas are missing too. Grafting may then be necessary.

The frontal sinus/base of skull repair/reconstruction including any dural repair (possibly needing local pericranial or galeofronteal flaps) will need to be finalized now.

TREATMENT

Conservative treatment

Conservative treatment is recommended when the dental occlusion is not disturbed and there is an acceptable facial contour with no other functional problems. There is more scope for this sort of treatment plan with an edentulous maxilla.

Open reduction and internal fixation

ORIF is the treatment of choice for most displaced fractures. The sequence illustrated is of a minimally displaced Le Fort II fracture on the right with more displacement on the left. Examination of the face shows no obvious NOE injury with a reasonable nasal contour and no disruption of the medial canthi. A step defect was palpable at the left infraorbital margin and there was no clinical evidence of orbital floor or wall problems. There is a Le Fort I component to the fracture that gives a much more pronounced occlusal discrepancy of anterior open bite. CT scanning helps to delineate the injuries in great detail compared with plain radiographs (Figures 57.1 through 57.3).

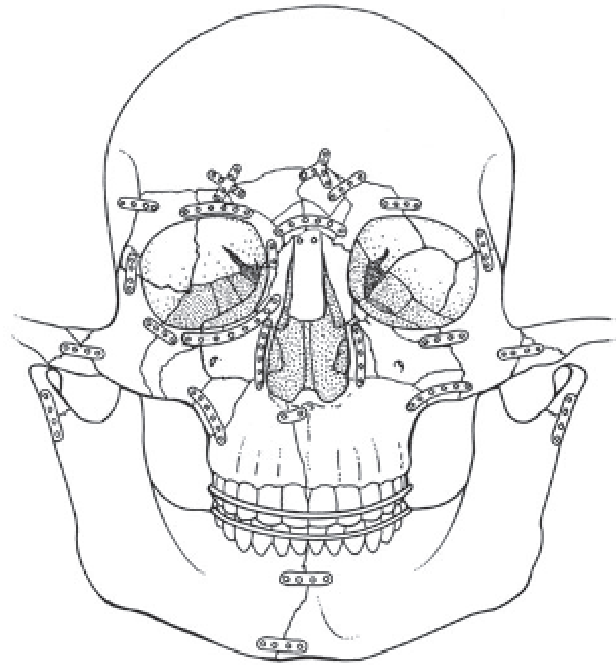

Figure 57.15 The last issue is to address any bone grafting issues within the orbit or onlayed on the nose. Soft-tissue aspects such as soft-tissue drape and suspension can be considered now. Any canthopexy issues can be finalized.

Access

ORAL

The incision is placed high up in the buccal sulcus and is the most usual access to low-level maxillary fractures. The dissection proceeds subperiosteally and care needs to be taken to keep in the correct plane when pieces of bone are displaced. In the area of the anterior maxilla, small pieces of comminuted bone may be best left attached to the periosteum so as to retain their viability.

FACIAL

These incisions would be as for access to the NOE complex (Chapter 59), orbital complex (Chapter 58) and zygomatic orbital complex (Chapter 60).

SCALP

For high-level midface fractures, the bicoronal incision is used to gain access to the lateral and medial orbit, as well as the frontonasal region as for isolated injuries in the NOE area (Chapter 59). This incision enables neurosurgical access to the skull at the same time, if required.

Reduction

Direct reduction of the fractures relies on visualization of the midface fractures using the access described. The Rowe's disimpaction forceps are placed under the dissected nasal mucosa. The other prong of the forceps (which

is usually padded with a silicone tube) is placed against the palatal mucosa (Figures 57.16 through 57.18).

The maxilla is typically mobile and displaced inferiorly and posteriorly. Occasionally, the maxilla is impacted superiorly and posteriorly, when it can be quite solidly impacted and difficult to mobilize. Anterior and inferior movement may require considerable manipulation in order to re-establish the correct anteroposterior and vertical dimensions and the intercuspation of the occlusion. This manipulation may restart or worsen the leakage of cerebrospinal fluid. There is a balance needed in manipulating the displaced maxilla so as to adequately reduce the fracture while minimizing further injury to the cranial base structures or orbital contents.

Sequencing midface fracture reduction when these fractures are part of panfacial injuries may involve complex three-dimensional (3D) issues for the restoration of function and re-establishing facial contours. Typically, the major mobilization of the maxilla is performed early on in the operation as any fixation applied elsewhere would be disrupted by this. There are real issues with the correct orientation of the maxilla in high-velocity injuries with bone loss and damage to neighbouring structures. In major craniofacial injuries, dealt with in collaboration with neurosurgeons, the mobilization of the maxilla is often performed only when the anterior cranial floor fractures are directly visualized following craniotomy and suitable brain retraction, so as to make sure further damage to the brain and dura does not occur.

Figure 57.16 Application of the left Rowe's disimpaction forceps.

Figure 57.17 Application of both Rowe's disimpaction forceps.

Fixation

The majority of midface injuries are fixed internally using low-profile titanium plates and screws (typically, 1.7 and 1.3 mm). They are usually placed in the areas of thickest bone which is most easily accessible, at the piriform aperture and the buttress of the zygoma in low-level fractures. At higher levels, the orbital rims and glabellar region offer the best bone for plate application.

The use of arch bars and temporary intermaxillary fixation (IMF) may be very helpful in maintaining the correct reduction during application of the plates. The correct positioning of the fractured maxilla is guided by the anatomic position of the fractured bones, as well as the intercuspation of the dentition. The dental occlusion may not be easily attained if there is a pre-existing abnormal bite and/or missing teeth. Impressions and study models taken pre-operatively with

Figure 57.18 Mobilizing the fractures using a careful rotatory movement.

fabrication of an occlusal splint help attain the correct dental bite at operation and may be very helpful.

A source of error in positioning of the maxilla is distraction of the mandibular condyles when achieving the final position of the maxilla prior to plating. These issues are exactly the same as the problems facing the surgeon in correct positioning of the maxilla in midface osteotomy surgery. The solution is to make sure the mandible is passive when applying IMF or hand holding the occlusion prior to plating.

Return to function

There are real advantages in having arch bars in position for minor post-operative occlusal problems when treating maxillary fractures. Elastic IMF may be sufficient to finalize any small discrepancy. Jaw opening and lateral excursion exercises are helpful in regaining functional movements.

OTHER TREATMENT METHODS USED OCCASIONALLY

Closed reduction and fixation using intermaxillary fixation

Only contemplated in minimally displaced fractures in order to optimize the occlusion. Issues to do with the restoration of correct facial height, anterioposterior displacement or lateral facial splay cannot be addressed.

Closed reduction and external fixation

Again, there are limitations with this treatment; however, the issues associated with facial height and anteroposterio position may be addressed to an extent. We would use this technique in the very rare situation of needing to stabilize the maxilla when packing the nose for a maxillary fracture complicated with a torrential midface haemorrhage.

The maxilla can be attached to an arch bar or cast splint by a projecting bar. Alternatively, projecting bars can be adapted from two bone pins placed directly into the premaxilla through small stab incisions, on either side at the alar base/nasal sill region, providing there is no comminution here. The projecting bars are connected to supraorbital pins or a halo frame.

Top tips

- Fractures of the midface are easily missed by inexperienced clinicians (often they are hidden beneath soft-tissue swelling). All components, including the orbital and eye, nasal and eyelid attachment and dental aspects are routinely underestimated.
- CT scanning is the imaging of choice. Scans often reveal extensive fractures unappreciated by clinical examination. These may not need active treatment, but it is useful to know of their presence.
- Work up for these injuries may involve other specialties. Surgical intervention is often delayed until associated head injury and facial swelling have resolved. This time should be utilized to develop a comprehensive surgical treatment plan.
- Having waited for the brain swelling to settle down, an operation if needed should not be delayed, despite any obtunded conscious level. Patients often make delayed recovery of brain function. Secondary correction is never as easy as primary anatomic repositioning of the basic midface structure. The planned intervention should be performed without further compromise to the damaged brain.
- The development of low profile (0.7 mm) and miniplate (0.3 mm) fixation systems has revolutionized our ability to reduce and fix these complex fractures.
- Despite apparent anatomic reduction at operation, post-operative elastic IMF using elastics is often required.

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58

Orbital trauma

MICHAEL WILLIAMS

CONTENTS

INTRODUCTION

Orbital trauma is common, the orbit being involved to some extent in approximately 40% of all blunt facial injuries. Most of these occur in conjunction with an outer orbital frame fracture including fractures of the zygomatic complex, maxilla and naso-ethmoidal fractures. However, there is a second group, in which a fracture of one or more of the orbital walls occurs with the outer orbital frame intact. Often described as 'blow out fractures', it is perhaps more accurate to describe this second group as isolated wall or floor fractures.

Complications of these injuries can be divided into functional (blindness and diplopia) which take priority in decision-making, and aesthetics including enophthalmos. Accurate assessment combined with meticulous attention to detail during the planning and operative procedure is essential to prevent or minimize poor outcomes.

ANATOMY

The orbit is comprised of an orbital frame or rim within which the walls can be conveniently described as floor, medial wall, roof and lateral wall (Figure 58.1). The orbital frame is strong and forms part of the midfacial buttressing system. However, the walls particularly the floor and medial wall are extremely thin accounting for the frequency of fractures in these areas. The lateral wall and roof are stronger and as a result, fractures of these regions are less common. It is important to note that the medial walls lie parallel to each other, and the lateral wall lies approximately 45% to the medial wall. The floor is concave upwards in the anterior third but then becomes convex upwards in the posterior two thirds (post-bulbar bulge blending into the key area medially).

Although there are four walls at the orbital rim, further back in the orbit the medial wall and floor blend together; at this point, the orbit becomes a three-walled pyramidal structure. This blending of the medial and lateral wall forms an important postero-medial bulge which has also been coined the 'key area'. This is an important area to replicate in orbital reconstruction to minimize post-operative enophthalmos. The anterior and posterior ethmoidal arteries pass through the medial wall and are important surgical landmarks. Passing through the floor is the inferior orbital fissure which contains no structure of surgical importance.

At the orbital apex, the medially located optic canal passes through dense bone of the sphenoid bone transmitting the optic nerve together with the central artery of the retina. More laterally, the superior orbital fissure transmits branches of the ophthalmic division of the trigeminal nerve together with the third, fourth and sixth cranial nerves. The 'superior orbital fissure syndrome' comprises

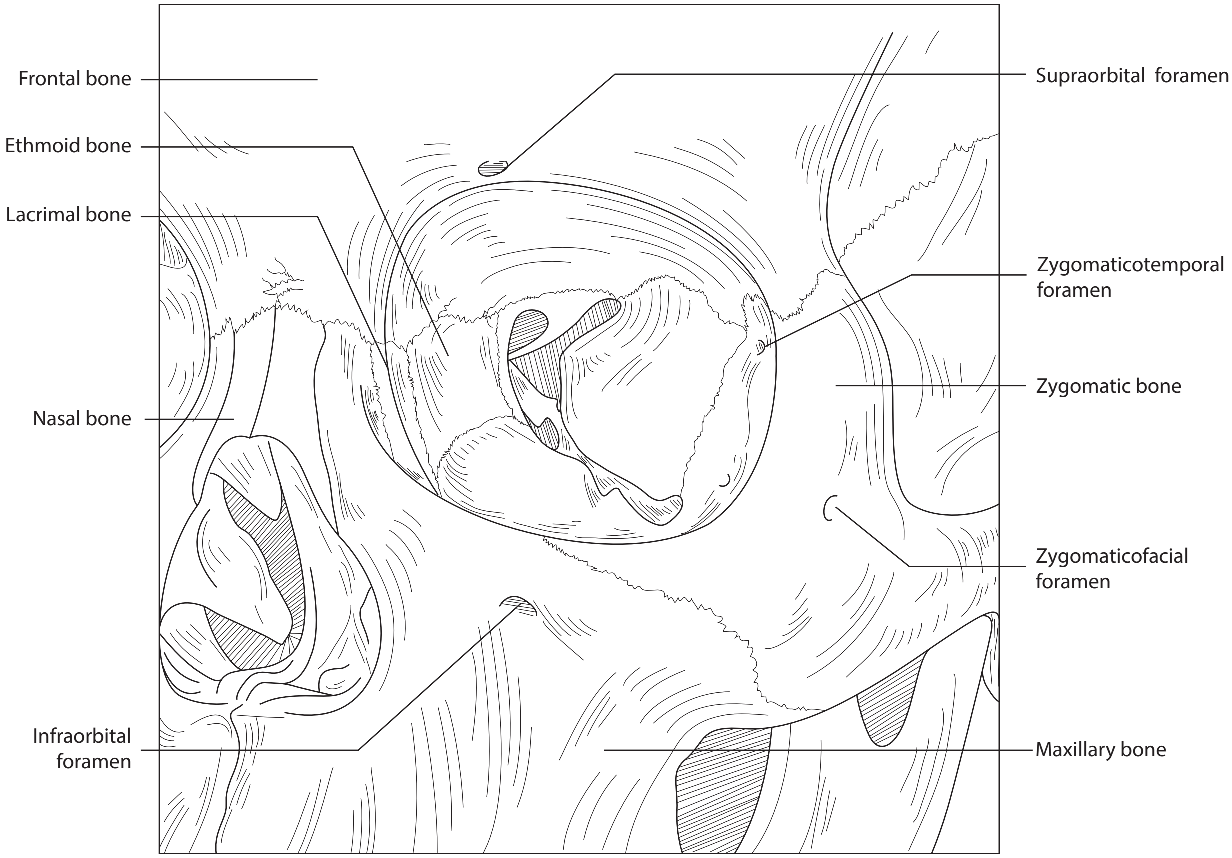


Figure 58.1 Orbital bones, frontal view.

total ophthalmoplegia, upper lid ptosis and anaesthesia in the distribution of the ophthalmic division of the trigeminal nerve, 'orbital apex syndrome' includes these signs in conjunction with blindness. Within the orbit, the globe is supported by Lockwood's suspensory ligament and moved by the extraocular muscles, it is enclosed in periorbital fat whose loss can contribute to enophthalmos. Anterior to the globe, the upper and lower tarsal plates are attached to the medial and lateral walls by the medial and lateral palprebal ligaments. This tense fascial sheath constitutes a 'fifth wall' of the orbital pyramid thereby forming a closed box. It is important to recognize this, for if orbital pressure increases following trauma, release of this fascial band by way of a lateral canthotomy can be sight saving, an important emergency surgical skill in the management of these injuries.

MECHANISM OF INJURY

Two theories have been proposed to explain the presence of isolated orbital wall fractures. In the first, an occluding force applied to the outer orbital rim leads to a transient increase in intra-orbital pressure leading to a 'blow out fracture'. The second theory proposes a transient deformation of the rim which remains intact but the transmitted force leads to a fracture within the orbit Figure 58.2 as orbital injuries rarely lead to significant ocular injury, this second theory is probably more likely.

INITIAL ASSESSMENT

Following a full systemic and maxillofacial examination, the orbital injury should be carefully assessed. The mechanism of injury is important in particular to differentiate between blunt and penetrating trauma. Visual acuity must be assessed at an early stage and enquiries made regarding the presence of double vision and numbness around the orbit. Traumatic optic neuropathy is uncommon and presents a challenging management problem; surgical exploration is difficult and expertise may not be available locally, there is little evidence to support the use of mega dose steroids in its management.[1]

Examination should include the peri-orbital soft tissues especially the lid, cornea and anterior chamber of the eye, looking particularly for the presence of hyphema, corneal injury and iris injury and importantly, the presence of contact lenses which should be removed. The presence of a subconjunctival haematoma without posterior limit indicates a likely breach in the orbital periosteum.

Examination proceeds with palpation of the outer orbital frame, following which eye movements are carefully assessed in the nine cardinal positions of gaze

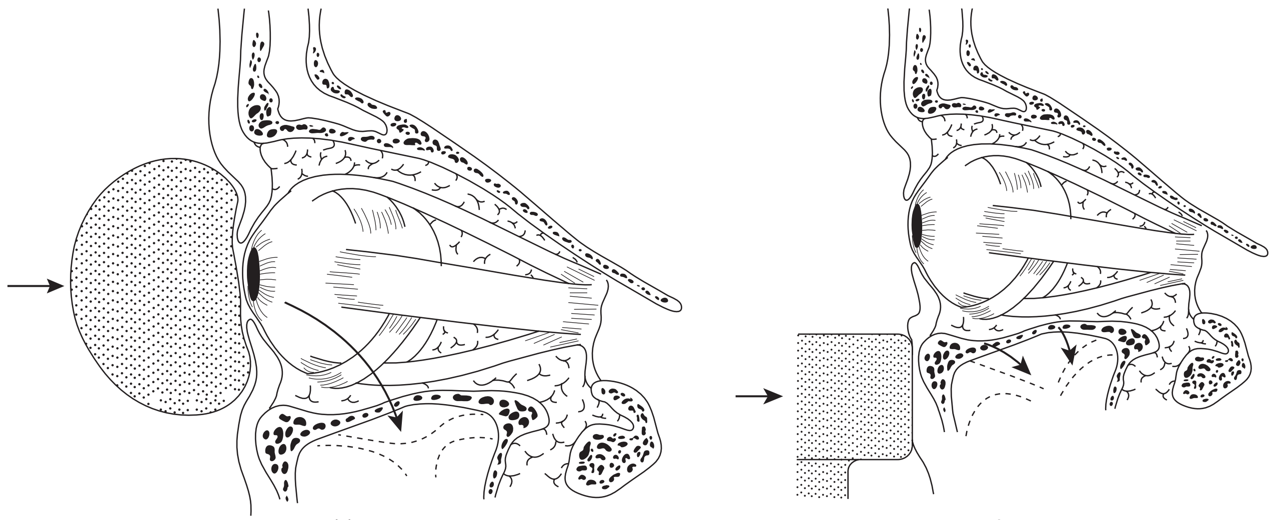


Figure 58.2 (a and b) Proposed mechanisms involved in blow-out fractures.

carefully documenting the presence of diplopia in any of these positions. Red colour desaturation is an important sign which when combined with swinging light test may indicate reduced optic nerve function, a relative afferent pupillary defect (RAPD).

In the unconscious casualty, pupillary reactions take on further importance and if the eye of the injured side is closed, then optic nerve function can be assessed with a bright light whilst monitoring the uninjured eye.

INVESTIGATIONS

Radiology

Plain radiographs are of limited value in isolated orbital wall injuries but the hanging drop sign may be noticed, and they are of value in assessing the outer orbital frame. However, the imaging modality of choice for orbital trauma is a fine cut spiral computed tomography (CT) which should include all four walls with coronal, sagittal and occasionally three-dimensional (3D) reformatting.

Orthoptic assessment

Orbital trauma should ideally be managed jointly with ophthalmic surgeons and an important component is preoperative orthoptic assessment. This will include clinical measurement of visual acuity and ocular motility, together with a cover test for near and distant vision. Any deviation is measured for consideration of prisms.

The Hess chart is a dissociation test allowing objective measuring and recording of ocular motility. The mobility of the injured eye being compared with the fellow uninjured eye.

Restricted movement is observed in the injured eye and overcompensation seen in the normal eye (Herrings Law) (Figure 58.3).

It is essential to assess and confirm the visual acuity of the contralateral, uninjured eye and to rule out pathology in this eye.

PAEDIATRIC INJURIES

Paediatric orbital fractures are less common, the walls being much thicker as a consequence of the under development of the associated paranasal sinuses. However, when they occur, they often lead to a true trap door green stick fracture often trapping peri-orbital tissue. These are commonly missed injuries due to absence of other signs[2] it is imperative to operate and release the entrapped tissues as soon as possible, many emphasizing within 5 days.[3]

TREATMENT

It cannot be overemphasized that ocular function is the single most important consideration in the management of these injuries. This takes on even greater importance should poor or absent vision exist in the uninjured eye. This would be a contraindication for surgical repair, hence the need for its accurate assessment. It may be entirely appropriate not to treat a minor degree of enophthamos in a patient who has normal visual acuity and no diplopia.

For non-isolated orbital injuries, it is essential that the outer orbital frame is treated first, the orbital wall factures are then repaired in exactly the same way as for an isolated wall injury.

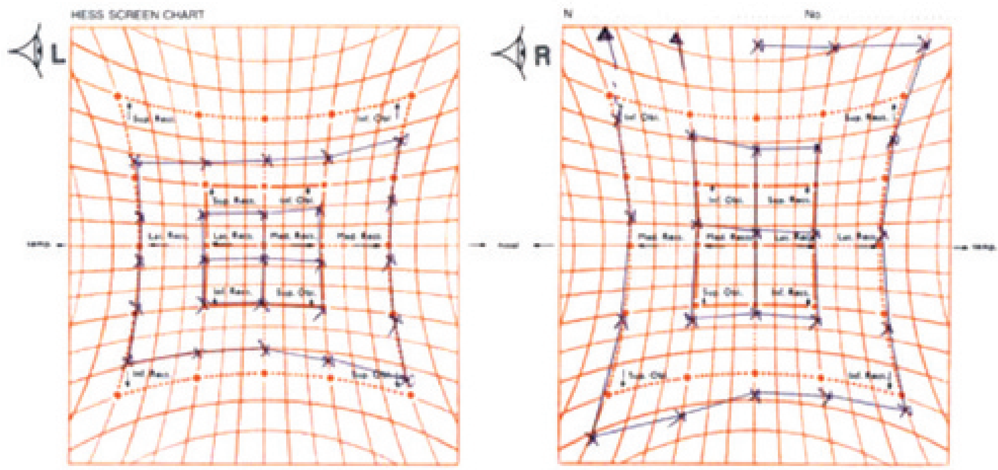


Figure 58.3 Hess chart indicating left orbital floor fracture. Note restricted movements in left chart but overcompensation in uninjured (right eye).

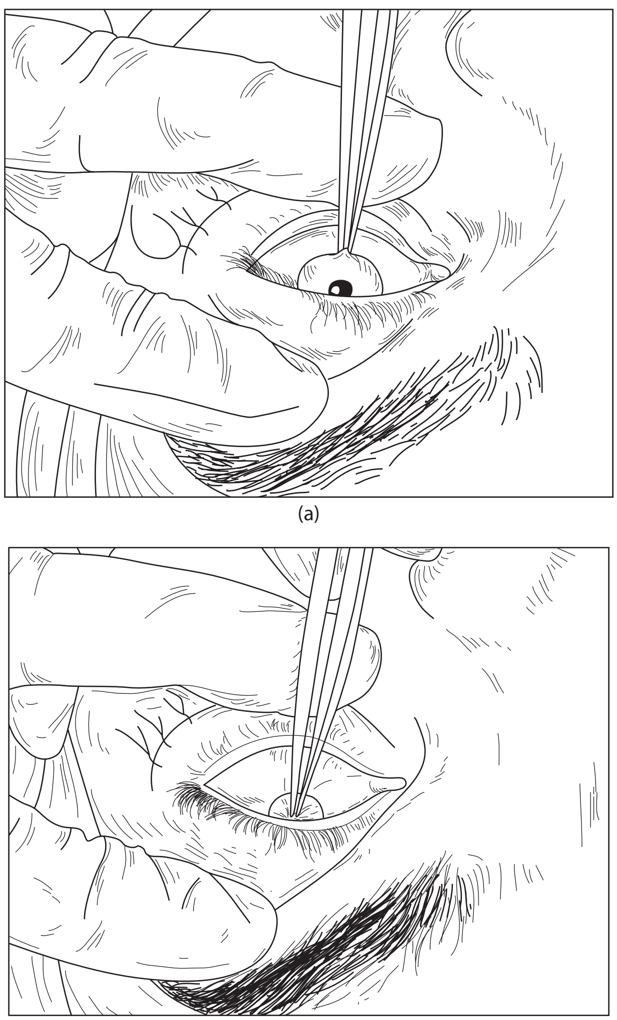


Figure 58.4 Forced duction test which should be performed pre-operatively and on completion of repair to exclude entrapment.

Treatment options for an isolated wall fractures are either conservative treatment or operative repair. Small isolated injuries with no evidence of enophthalmos or diplopia can be safely observed and in many cases, no operative intervention will be required. However, larger defects are likely to lead to a significant enophthalmos which can be difficult to correct, accordingly most would favour early operative repair. Other indications for operative intervention would include significant diplopia or obvious entrapment of peri-ocular tissues.

OPERATIVE PROCEDURE

Positioning

The patient is placed supine on the operating table with a slight degree of head up tilt with modest hypotension provided by the anaesthetist. Both eyes should be exposed and protected and a forced duction test performed to assess any restriction in ocular motility (Figure 58.4). There should be due attention to corneal protection, this may be provided either in the form of a corneal shield if a trans-conjunctival incision is utilized or a temporary tarsorophy if a lower eyelid incision is used.

Exposure

The orbit can be exposed through a variety of incisions depending on which walls are fractured and the amount of exposure required. The floor can be approached by either a lower eyelid incision or a trans-conjunctival incision with or without a lateral canthotomy. There are three lower eyelid incisions (Figure 58.5): the subciliary (or blepharoplasty) incision, the midtarsal incision and the

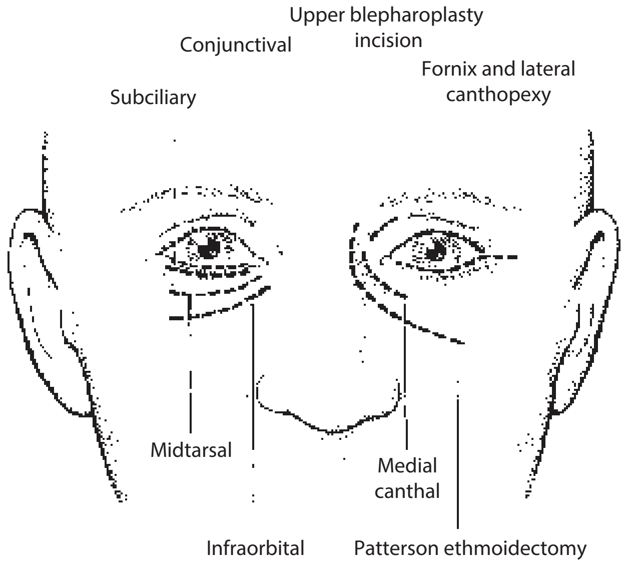
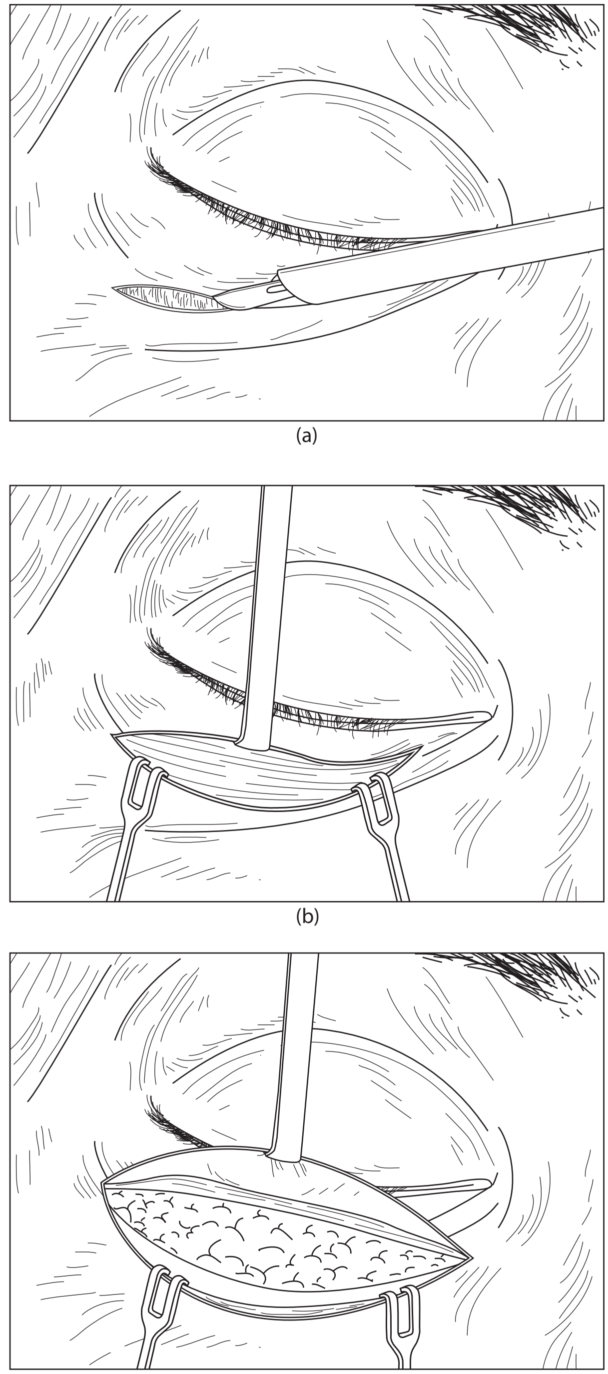


Figure 58.5 Surgical approaches to the orbital floor and walls.

infra-orbital incision. With regards to complications, the infra-orbital incision has a very low incidence of ectropion but an increased incidence of poor scarring. The subciliary or blepharoplasty incision has a very low incidence of scarring but an increased incidence of ectropion although this can be reduced by not suturing the wound and leaving a cuff of orbicularis occuli attached to the lid margin. The midtarsal incision combines the advantages of both these procedures having very acceptable scarring together with a low incidence of ectropion[4] and is the author's preferred lower lid incision. The incision is carried through skin followed by careful sharp dissection through orbicularis oculi to reach the tarsal plate. Meticulous haemostasis with bipolar forceps is essential and further aided by pre-operative infiltration with lidocaine and epinephrine. Using careful retraction with a Desmare retractor, a clear plane is revealed between orbicularis oculi and tarsal plate which is followed by sharp dissection onto the anterior face of the orbital rim (Figure 58.6).

The trans-conjunctival incision gives very generous exposure of the orbit and is probably the approach of choice for larger defects. It can be made pre or post-septally, the pre-septal approach is more complicated with few advantages and the post-septal approach is generally preferred. With the lower lid retracted anteriorly with a Desmare retractor, a malleable retractor can be placed directly behind the orbital rim, thus placing the tissues under tension (Figure 58.7). The conjunctival incision is then made, preferably made with a needle point diathermy following which the retractors are repositioned inside the wound allowing further dissection, again to the anterior face of the orbital rim.

Whichever incision has been used the periosteum on the anterior aspect of the orbital rim is now incised. It is important to keep the dissection on the anterior surface



(a)

(b)

(c)

Figure 58.6 (a) Midtarsal skin incision. (b) Retraction of wound edge revealing plane betweenxs orbicularis occuli and the tarsal plate; (c) incision on anterior wall of orbital rim to give access to orbital floor.

of the orbital rim since this minimizes herniation of peri-orbital fat.

Greater exposure of the orbital floor can be gained by combining the trans-conjunctival incision with a lateral canthotomy. For this procedure, a small skin incision passes through the fornix between the upper and lower eyelids following which the lower limb of the lateral

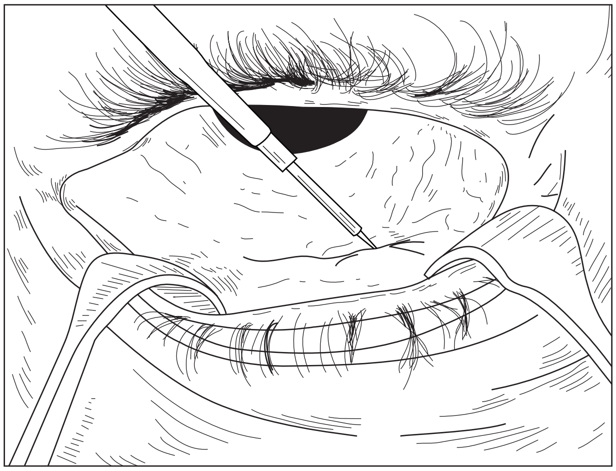


Figure 58.7 Trans-conjunctival incision. Retraction of lower eyelid with Desmare retractor combined with tension applied with blunt malleable retractor inside orbital rim to place tissues under tension prior to division with needle point diathermy.

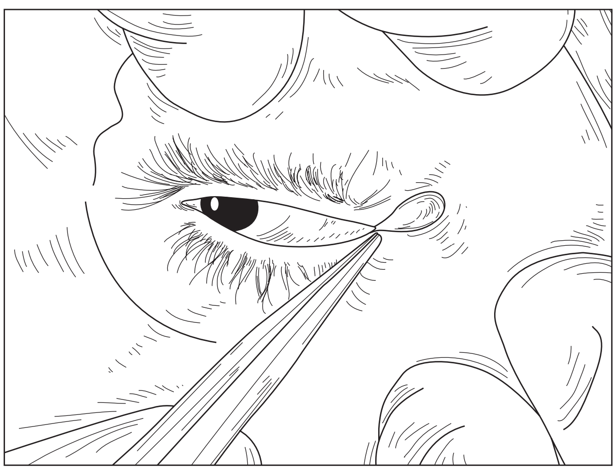


Figure 58.8 Lateral canthotomy, following skin incision the lower canthal band is identified and divided.

canthus can be divided (Figure 58.8). If this incision is utilized it is generally more convenient to perform the lateral skin incision and canthotomy prior to dividing the conjunctiva.

Following incision of the inferior orbital rim periosteum, the periosteum is easily elevated over the rim and dissection proceeds in a downwards direction before passing posteriorly until the anterior margin of the floor defect is identified, dissection should be careful and precise to avoid enlarging the defect. At this point, it is important to 'out flank' the defect and since the lateral wall is less commonly fractured it seems more convenient to follow this as the next step. The inferior orbital fissure is then identified and can be safely coagulated between bipolar forceps and then divided to give much improved access (Figure 58.9).

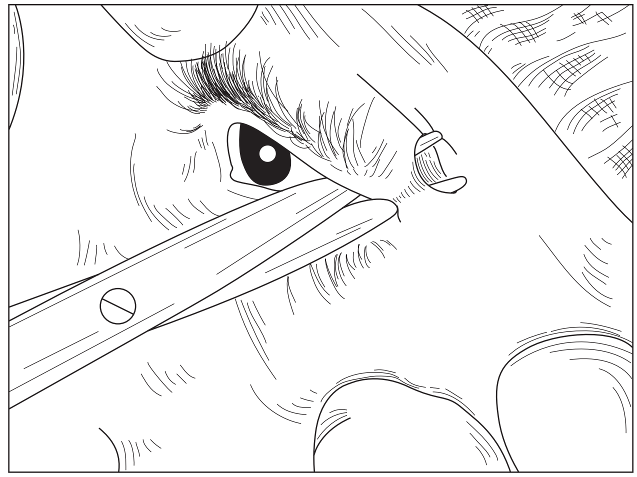


Figure 58.9 Division of inferior orbital fissure after coagulation with bipolar forceps greatly increases exposure.

The presence of a significant medial wall fracture (often in combination with a floor fracture) requires a further incision to gain proper access. The established approach to the medial wall is via a coronal flap. The incision extends from a pre-auricular incision passing coronally across the scalp to be completed by a pre-auricular incision on the contra-lateral side. The so called stealth variant zigzags the incision across the scalp to allow disguising of the scar by hair growth although in the author's experience a wavy line incision is easier to raise and avoids hair loss at points of the zigzags.

The incision is ideally made with a ceramic blade passing through skin and the aponeurosis with careful vascular control provided with Raney clips. The flap can be rapidly mobilized in the sub-galeal plane to a point just above the fronto-zygomatic suture at which point the periosteum is incised and the incision carried laterally through the outer layer of the deep temporal fascia to the root of the zygomatic arch. By this means, the facial nerve is protected and temporal hollowing is minimized. By continuing dissection in a sub-periosteal plane the supraorbital notch is identified. If the supraorbital nerve is lying in a foramen then the lower margin of this can be osteotomized to allow the supra-orbital nerves to be freed. The peri-orbital rim periosteum is dissected and carried down the medial aspect. Flap mobility can be improved by incising the periosteum on the under surface of the flap in the midline. By proceeding posteriorly, generous exposure of the medial wall is obtained. It is important to complete any lower eyelid incisions before raising a coronal flap as it often leads to significant oedema in the lower eye lids.

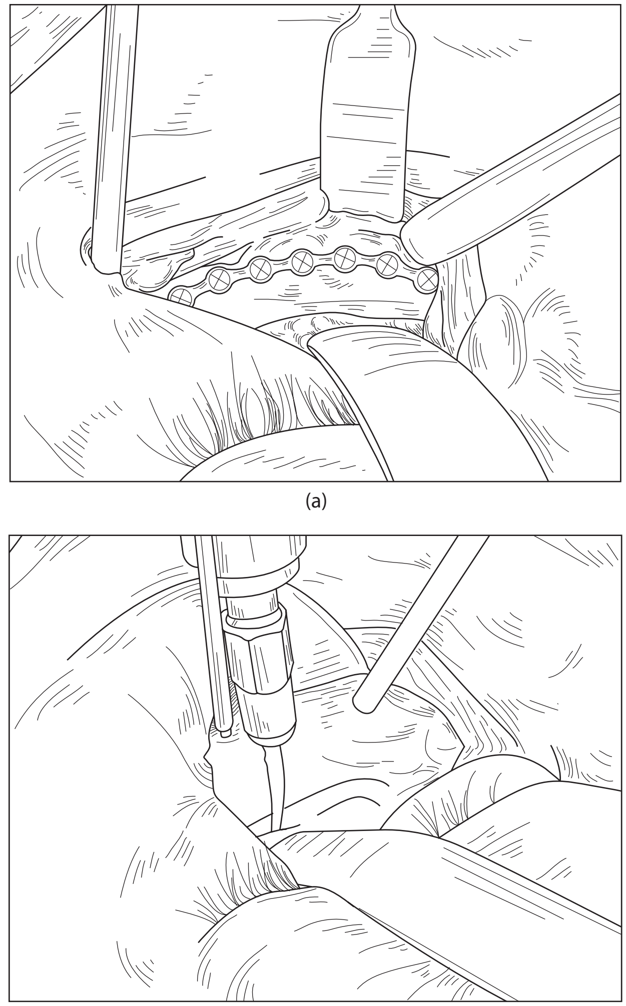
The coronal flap can have significant morbidity including poor scarring, alopecia, temporal hollowing. Injury to the temporal branch of the facial nerve and numbness in the distribution of the supraorbital and supratrochlear nerves can also occur. Its use is probably more appropriate in pan facial injuries.

Less invasive approaches such as the trans-curuncular incision which is essentially a medial extension of the trans-conjunctival incision gives adequate exposure to the medial wall without such morbidity.

Dissection posteriorly along the medial wall almost certainly will require ligation or diathermy of the anterior ethmoidal vessels.

The posterior limit of dissection should ideally be to the posterior margin of the defect but in deep orbital trauma there is clearly a limit to how far dissection can proceed without endangering the optic nerve. It has been suggested that sub-periosteal dissection should not proceed beyond 35 mm from the orbital rim but this guideline should not be used in the presence of an orbital rim fracture. Other guidelines are the level of the posterior ethmoidal artery. More recently, stereotactic navigation has been suggested but this is not widely available and a recent paper has reiterated the importance of proper anatomical knowledge in such dissection.[5]

On completing the sub-periosteal dissection, exposure of the defect can be improved by undertaking a marginal orbitotomy.[6] For this procedure, the segment of inferior orbital rim to be removed is marked and a low profile microplate adapted and temporarily fixed to bridge the proposed osteotomy (Figure 58.10). The plate is removed and the orbitotomy completed. Removal of this segment of infra-orbital rim certainly improves access but is not always essential, furthermore, it is extremely difficult to undertake in the presence of an orbital rim fracture.



(a)

(b)

Figure 58.10 (a) Bridging plate adapted to orbital rim over proposed osteotomy site; (b) osteotomy completed with micro saw.

Reconstruction

Following complete exposure of the defect, the surgeon is now in a position to plan the reconstruction. There are essentially two choices either to use autologous bone or an alloplastic material.

Historically, the use of alloplastic materials was associated with complications including infection and extrusion and as a result, autologous bone became the preferred reconstructive material. Autologous bone can be conveniently harvested from the calvarium if a coronal flap has been raised. Other sites include the anterior wall of the ipsilateral maxillary sinus if intact, iliac crest or rib. However, there can be significant donor morbidity from bone graft harvest and also unpredictable resorption[7] these factors together with the poor accuracy of orbital volume reconstruction have lead to new interest in alloplastic materials.[8] There is now a wide range of such materials which can be divided into resorbable and non-resorbable groups.

Resorbable membranes such as polydioxanone (PDS) sheet and poly-lactic/glycolic acid are thin and malleable but are not suitable for large defects since they lack sufficient structural rigidity and have unpredictable resorption.[9]

Non-resorbable materials include titanium mesh and polyethylene membranes (Medpore). Titanium mesh can either be provided in simple plain sheet form which can be cut to shape but most manufacturers are now providing pre-formed adaptable sheets allowing a very accurate 3D reconstruction (Figure 58.11) particularly if used in conjunction with an computer-generated stereolithographic model constructed using a ‘mirror image’ of the non-injured side.

Polyethylene sheet is very malleable but does have some degree of memory. It has the advantage of providing a smooth surface against the orbital tissues which makes removal (if necessary) slightly easier than titanium mesh. Fixation is less easy than with titanium mesh and can be achieved either with a titanium screw behind the orbital rim or with a PDS suture. More recently, polyethylene sheeting has been made over a titanium mesh framework combining the advantages of both materials.

A recent innovation is the production of anatomically preformed orbital plates. Available in small and large format with left and right sides they are also supplied with anatomical concave malleable retractors helpfully with calibration markers and these have revolutionized orbital

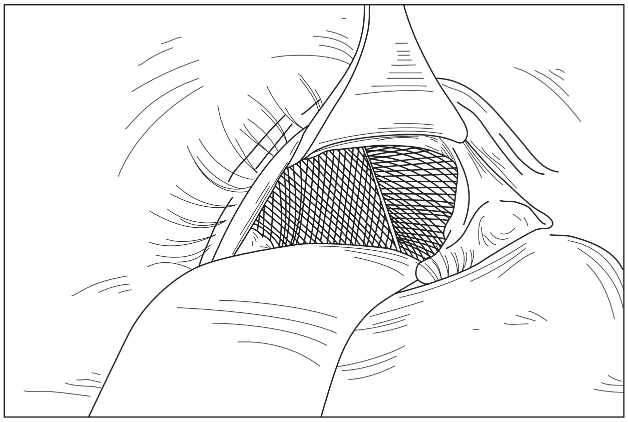


Figure 58.11 Preformed titanium mesh allowing accurate repair of complex orbital fractures.

reconstruction. The plates have a segmented design allowing adaptation of both the medial wall height and floor length together with fixation screws to accurately locate the plate onto the orbital rim. Recognizing the importance of the posterior bulge, the plates have a 'rigid zone' in the posterior orbit to allow a consistent form in this region (Figure 58.12).

Following insertion of the implant, careful assessment is made with regards to correction of enophthalmos and the pupillary level and the forced duction test is repeated (Figure 58.3b). Once the surgeon is happy with the reconstruction, the implant is fixed into position ideally with titanium screws.

In cases of massive destruction of the orbital walls, custom-made implants can be made via a 'virtual stereolithographic model' from CT data these can lead to accurate restoration of orbital volume and form, essentially using a mirror image of the non-injured side.

Following implant fixation, wound closure can be made over a small vacuum drain and it is important to close the periosteum to allow proper suspension of the malar fat pad, the muscle layer is not closed and the skin gently opposed with interrupted 6-0 nylon sutures. For trans-conjunctival incisions, following closure of the periosteum, there is debate as to whether the conjunctiva should be closed with many preferring not to close the conjunctiva to reduce the risk of entropion. If a coronal flap is being utilized, it is important to carefully close the aponeurosis ideally using running 2-0 braided resorbable suture on a round bodied needle. Following this, the skin can be conveniently closed with skin staples but the preauricular incision should be carefully closed in layers with 6-0 nylon sutures to skin. Two large vacuum drains should also be used and it is advisable to apply a pressure dressing for the first 24 hours.

Post-operative care includes careful eye observations to include visual acuity, pupil reactions, ocular movements and most importantly increasing pain. The patient should be nursed with his head elevated to reduce peri-orbital swelling. He should be encouraged to mobilize his eyes as much as possible, and avoid nose blowing.

COMPLICATIONS

Blindness

This is the most important complication of orbital surgery, the incidence being extremely low at approximately 1 in 1500. Visual impairment may follow either injury to the optic nerve or ophthalmic artery during the surgical procedure or by retro bulbar haemorrhage in the immediate post-operative period. Close observation in the post-operative period is mandatory and clear protocols need to be established.

Diplopia

Diplopia may be initially worse following surgery due to oedema or haematoma but is likely to improve over the next few weeks. Long-term complications include enophthalmos, poor scarring and soft-tissue distortion.

Enophthalmos

Enophthalmos is largely due to inaccurate restoration of orbital volume often requiring secondary correction (Figure 58.13).

Poor aesthetics

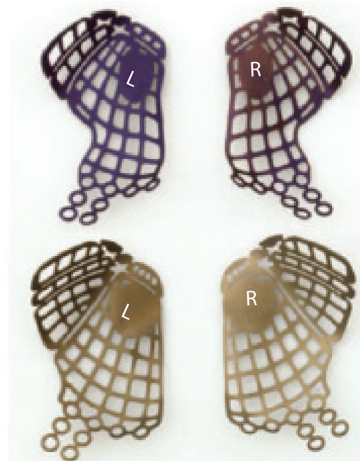
Poor scarring is more common with infra-orbital incisions and rare with trans-conjunctival and blepharoplasty incisions. Malposition of the lateral canthus can occur and many suggest suturing the canthus with a non-resorbable suture to be hole drilled in the lateral rim of the orbit, others have suggested dividing the lower rim of the canthus through the tarsal plate which can be more accurately sutured to the correct position.

Retrobulbar haematoma

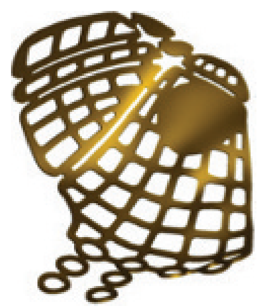
A retrobulbar haematoma follows bleeding within the orbit and can either be within the cone of extra-ocular muscles or outside this cone. As bleeding continues, pressure increases within the orbit leading ultimately to pressure on the optic nerve head with the clinical signs of ophthalmoplegia, reducing visual acuity and pain leading to a fixed dilated pupil. This can occur either following the initial injury or following surgical correction. First aid measures include the use of steroids, Mannitol and Acetazolamide combined with a lateral canthotomy

Preformed Orbital Plates

– 0.4mm thick
– Large (bronze) and Small (purple)
– Left and Right implants
– Work with matrixMIDFACE 1.55mm screw
– Can be stored in the MatrixORBITAL Set or MatrixMIDFACE Plate module
– TiCP, mallable
– Available in sterile



Large (gold) **Small (dark purple)**



MatrixMIDFACE Preformed Orbital Plates

Orbital Retractors

– Minimize orbital soft tissue prolapse
– Provide soft tissue protection
– Large and small retractor ends
– Right and left retractors
– Stainless steel, malleable

Figure 58.12 Synthes Matrix preformed orbital plates and retractors.

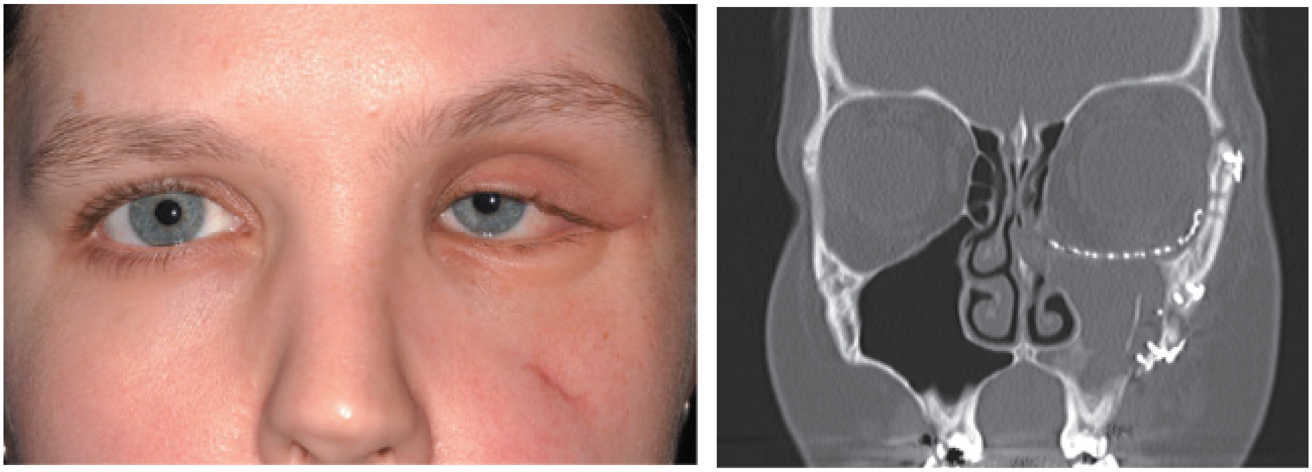


Figure 58.13 Enophthalmos clinical sequelae and imaging: The titanium mesh implant is malpositioned, being too low on the medial wall (note the natural upwards and medial slope of the uninjured right floor which has not been replicated) which has led to an expansion of orbital volume and enophthalmos as a consequence.

to give temporary control prior to urgent formal surgical exploration and drainage.

More recently, the concept of a retrobulbar haemorrhage has been challenged and a better term may be orbital compartment syndrome[10] since in many cases the signs and symptoms are secondary to oedema rather than true haematoma. It has been suggested that tonometry may provide some guidance on which cases require operative intervention and which can be safely observed;[11] however, many would still recommend formal exploration in the presence of such signs.

Top tips

- Remember sight comes first, visual acuity and full ophthalmic examination for all.
- Close working relationship with ophthalmic surgeons.
- Maintain high index of suspicion of orbital injury in all midthird trauma.
- Assess integrity of orbital frame.
- Accurate recording of size and location of defect using high-resolution axial scanning with coronal and sagittal reformatting.
- Children require urgent treatment.
- Plan access incisions with regard to size and location of defect, coexisting fractures and choice of repair material.
- Close observation in the post-operative period.

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59

Craniofacial trauma, including management of frontal sinus and nasoethmoidal injuries

ROBERT P BENTLEY

CONTENTS

BACKGROUND

Previously, patients sustaining craniofacial trauma were routinely treated separately by several disciplines independently often resulting in poor outcomes. However, it is now widely accepted that this group of patients are treated optimally by a multidisciplinary team approach in a neurosurgical centre with ready access to modern imaging technology and neurosurgical high dependency facilities. It has been this development, together with the realization that the first time is the best time to treat these injuries, that has led to the significant reduction in aesthetic and functional morbidity associated with such injuries.

CLASSIFICATION

While accepting the simple classifications of simple linear fractures of a given bone or fossa involved, a more useful working classification of fractures involving the frontobasilar region was suggested by Bernstein et al. who divided the injuries into central, lateral and complex groups. The central group includes fractures involving the central anterior skull base and cribriform region adjacent to the frontal, ethmoidal and sphenoidal sinuses (Figure 59.1). The lateral group include frontal bone fractures associated with the orbital roof, but lateral to the frontal sinus (Figure 59.2) and finally the complex group involving all areas often bilaterally (Figure 59.3).

This classification helps relate the fracture pattern to involvement of adjacent structures and the possible functional sequelae. Thus, central injuries are far more likely to involve sinus-related problems, whereas lateral injuries are more often associated with orbital and globe issues. Second, the classification helps plan the craniotomy to gain sufficient access to perform a safe surgical repair.

CLINICAL ASSESSMENT

Due to the mode of injury, patients with craniofacial injuries will often present with associated head injury. In addition, 30% of such patients will have another major life-threatening injury elsewhere in the body and up to 20% will have an associated cervical spine injury. It is therefore imperative that the principles and management of advanced trauma life support (ATLS) are applied to this group of patients (Figure 59.4).

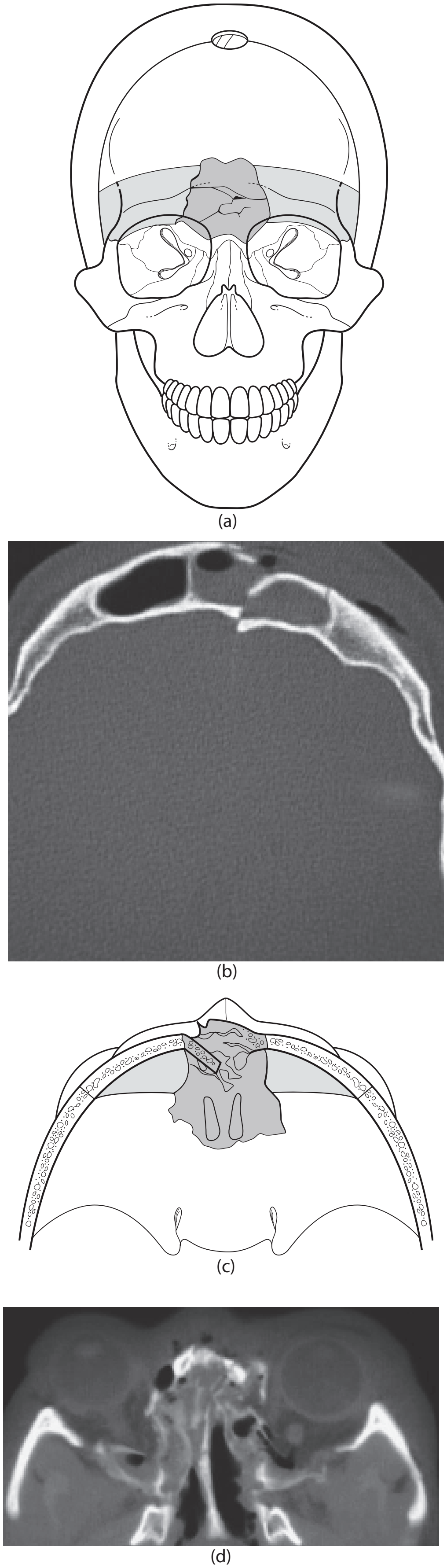


Figure 59.1 Central injuries.

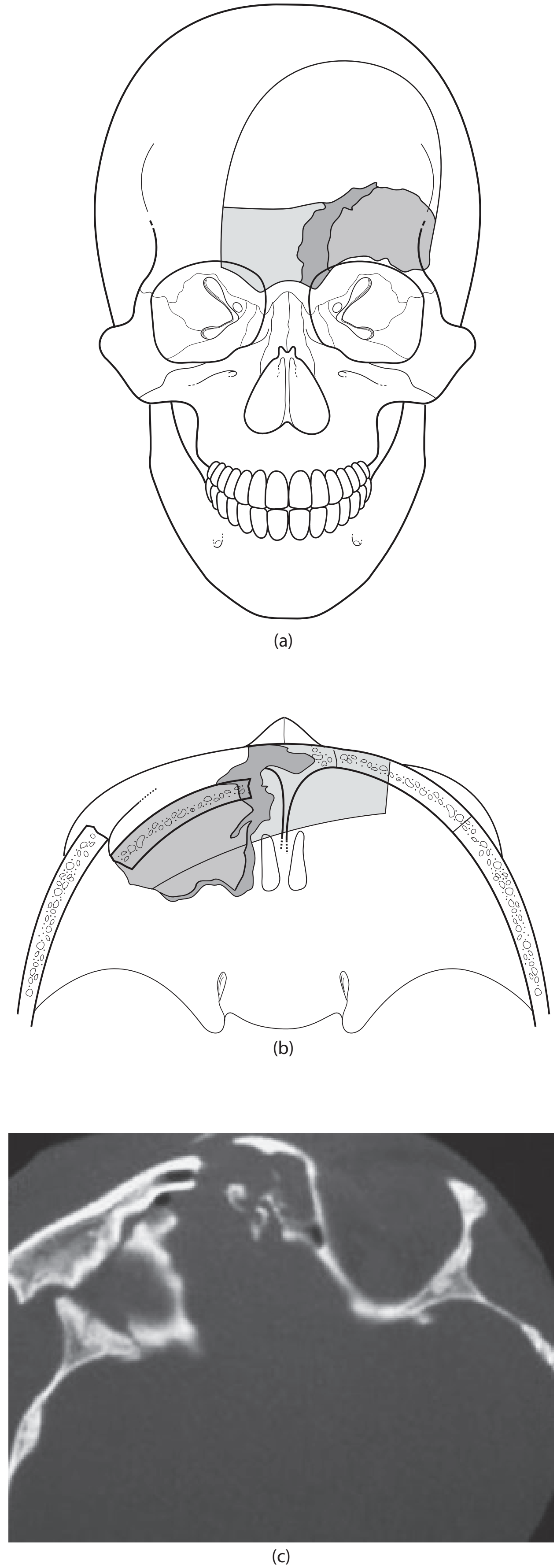


Figure 59.2 Lateral injuries.

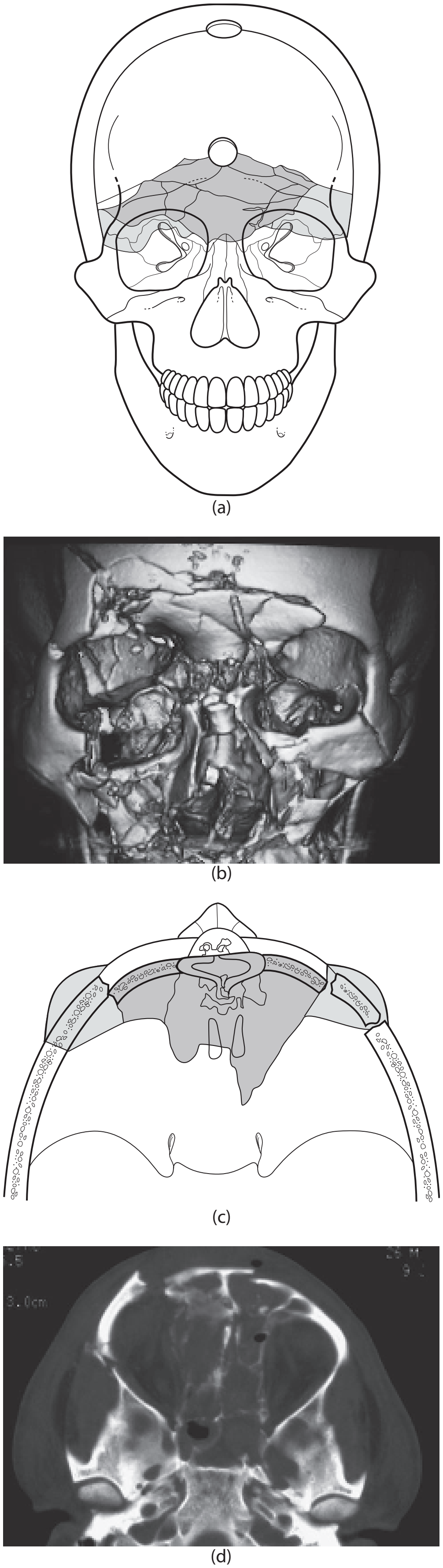


Figure 59.3 Complex injuries.

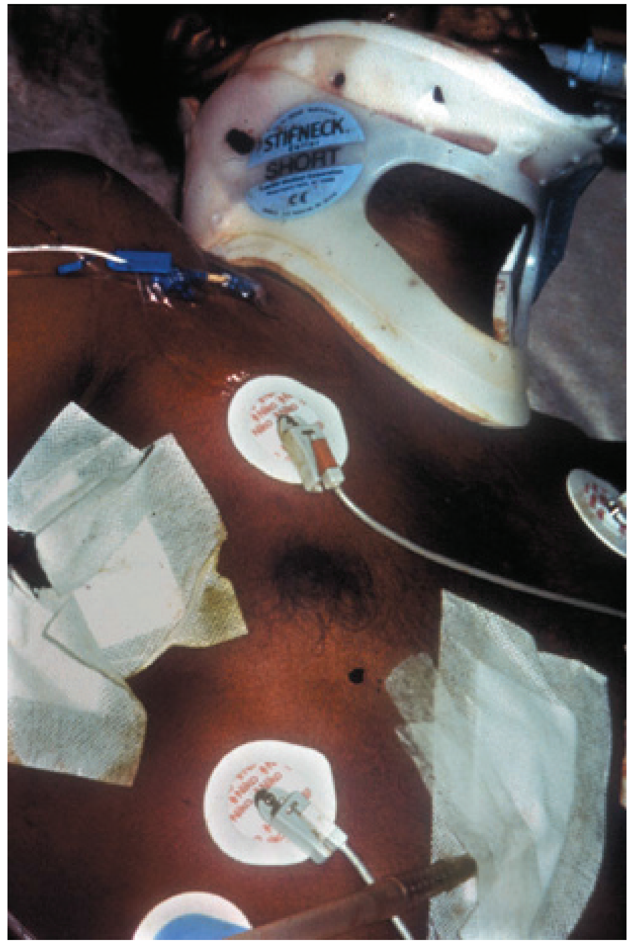


Figure 59.4 Multiple injured patient with craniofacial injuries.

Craniofacial assessment should include a full neurological examination paying particular attention to cranial nerve deficits. Ophthalmic assessment is mandatory and specialist help should be sought from an early stage even in the unconscious and intubated patient.

Any nasal or middle ear discharges should be tested for beta-2 transferrin to detect the presence of cerebrospinal fluid (CSF).

RADIOLOGICAL ASSESSMENT

The technical aspects have already been dealt with the relevant section on radiological assessment of facial trauma, but suffice to say the role of high speed spiral computed tomography (CT) scanners and improved computer software has revolutionized the ability to produce high quality images quickly with the least embarrassment to the patient and permits accurate visualization of the fracture patterns in all three planes with three-dimensional reconstructions, aiding the surgeon to develop an operative plan.

INDICATIONS FOR COMBINED CRANIOFACIAL REPAIR

The indications for combined craniofacial repair include the following:

- Central injuries, involving significant displacement of the anterior fossa floor and posterior wall of the frontal sinus
- Lateral injuries, involving the roof of the orbit leading to contour deformity, globe displacement or ocular motility disturbance
- Compound injuries with penetrating injuries or bone loss
- Growing fractures with dural lacerations, involving the orbit
- Surgical goals of a combined repair fall into two broad groups. First, to prevent the late sequelae of infection, cosmetic deformity and lastly functional deficits.

Principles underlying prevention of late infective sequelae

The principles underlying prevention of late infective sequelae include

- Accurate dural repair
- Achieving a functionally safe frontal sinus
- Repair of a deficient anterior skull base
- The use of vascularized peri-cranial flaps to help seal off the dura from the nasal cavity

Dural tears in communication with the nasal cavity and paranasal sinuses are common and place the patient at an increased risk of developing meningitis. There is no doubt that risk of infection is significantly increased by the presence of a CSF fistula. This may be reduced, but not abolished, by the use of antibiotics but may be reduced significantly by achieving a dural closure. The problem areas are not those cases where CSF leaks persist, but those that stop within a relatively short space of time and no formal repair is undertaken. Repair should be undertaken if the CSF leak has not stopped after 14 days.

Principles underlying prevention of post-traumatic cranio-orbital deformity

The key to craniofacial repair is the accurate reassembly of the frontal bandeau which helps define a platform for facial height, width and projection, as well as allowing for accurate restoration of the convexity of the orbital roof, reducing the adverse effects on globe motility and minimizing the risks of altered orbital volume.

TIMING OF SURGERY

Surgery is usually directed towards life-saving neurosurgical compromise in the first instance based on Glasgow Coma Scale (GCS) and CT findings supplemented with intra-cranial pressure monitoring where necessary. Assuming that these aspects have been addressed a time frame of 10–14 days has been shown not to adversely affect the patient's outcome.

SEQUENCING OF SURGICAL PROCEDURE

Anaesthesia

The choice of intubation may be normal oral intubation, but if injuries include pan-facial fractures requiring stabilization of the occlusion, then other options include nasal intubation, submental intubation with a possible tube switch to an oral tube at the end of the procedure to address the nasoethmoidal injuries. Tracheostomy may be required, especially if a prolonged period of post-operative ventilation is required due to a resolving head injury or thoracic injuries.

Position of the patient

Usually, the patient would be placed supine in a head ring ensuring enough support to prevent excess head mobility, but allowing good access to the vertex and posterior scalp facilitating the coronal surgical approach and possible need to harvest calvarial grafts.

Adequate exposure

The abilty to restore normal form, function and aesthetics can only come from the anatomical reduction of the facial skeleton and it is a prerequisite of this that all fracture sites should be exposed in a subperiosteal plane. Fortunately, previous experience has shown that due to the abundant blood supply in the head and neck region. Such a procedure is safe and does not lead to devitalization of the bone as long as it is firmly immobilized and the soft tissues are accurately redraped.

Adequate exposure may be achieved by a coronal approach which may be modified depending on the fracture pattern to allow for various forms of peri-cranial graft to be used or extended to allow access further down to the midfacial and condylar regions.

Consideration of the placement of the incision must take into account the hairline of the patient. The incision is best placed along the vertex of the scalp in a wave form so that the first curvature is directed posteriorly from the tragus ensuring the incisions amplitude is around 3 cm. It is important that the anterior aspect of the incision are kept within the hair line.

Pre-operative whole head shaving is not necessary, but parting of the hair with a comb helps positioning of the incision and this can be further aided by performing

a 3-cm width shave with clippers and a hair razor. The hair may be treated liberally with chlorhexidine gluconate hand wash which acts as a hair gel and allows the hair to be gathered into clumps and secured with elastic bands.

The whole site can be prepared with aqueous iodine after eye shields and simple eye ointment have been applied to each eye. Alternatively, temporary tarsorrhaphies may be performed with a 4/0 monofilament suture with an atraumatic needle utilizing 1-cm sections of paediatric silastic feeding tube to help prevent undue pressure on the delicate skin of the eyelids while maintaining protection. It is important to pass the needle through the grey line of the lids to ensure some of the tarsal plate is engaged helping prevent tearing of the eyelid skin (Figure 59.5).

Surgical drapes are secured to the posterior aspect of the proposed incision line with staples and a urology pouch secured in a similar fashion helps to collect the irrigation fluid. The patient is positioned slightly head up taking care to liase with the anaesthetist, as unexpected air emboli may infrequently complicate any cranial procedure with head up tilt on the table (Figure 59.6).

Figure 59.5 Temporary tarrsoraphies.

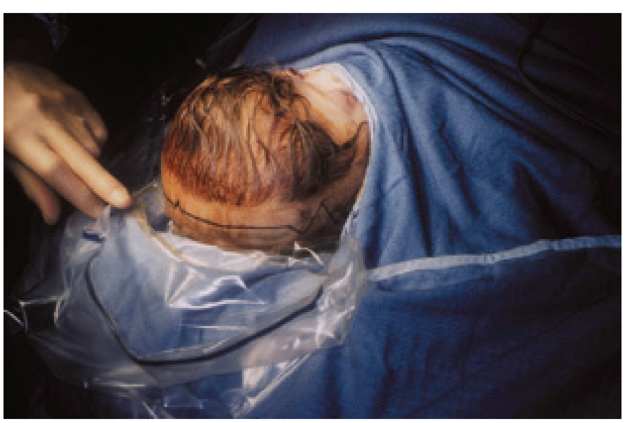
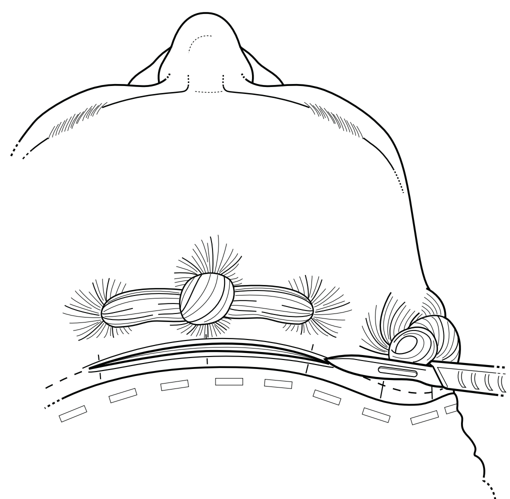


Figure 59.6 Patient preparation, positioning and draping.

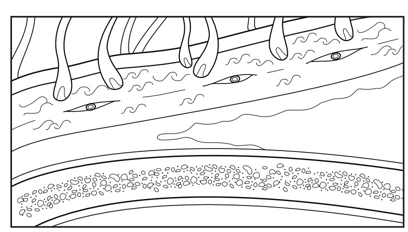
INCISION

The incision may be outlined using a pen and ink, preferably Bonney's blue, and the margins of the wound may be crosshatched with a scalpel. A green needle may be used to tattoo marks using ink adjacent to the incision. The permanency of the marks may be improved by placing one's finger over the hub of the needle and passing the needle into the scalp tangentially twice ensuring good passage of ink into the tissues. Increased haemostasis may be achieved by injection of a 1 in 200,000 epinephrine (adrenaline) containing local anaesthetic solution into the subgaleal space. Distension of this space has the added benefit of defining the plane for subsequent dissection.

The initial incision is performed with a No. 10 scalpel blade to the level of the hair follicles in the mid part of the outlined flap for a distance of 5 cm (Figure 59.7). The incision is deepened using a needle-point diathermy (Colorado micro needle®), set to minimize heat generation, but sufficient to help easy dissection down and through the galea to enter the subgaleal space. This procedure may be aided with gentle traction upwards and outwards with skin hooks inserted into the wound margins. This not only gives good access, but helps haemostasis. Having located the subgaleal layer, further dissection is achieved by placing McIndoe scissors with their tips up beneath the galea and opening the points widely. This action creates a pocket which may be elevated by the skin hooks and clear of the



(a)



(b)

Figure 59.7 Initial incision.

underlying pericranium, so that extension of the incision along the galea can be achieved with the cutting diathermy without damaging the pericranium (Figure 59.8). As dissection progresses and the scalp flaps become more mobile, haemostasis is obtained with the use of bipolar forceps to accurately minimize the damage to the adjacent hair follicles. Rather than the use of Raney clips, this technique helps to cut down haemorrhage at the end of the procedure during wound closure and leads to a less hurried and accurate closure. Dissection progresses inferiorly into the pre-auricular region below the level of the superior temporal line keeping close to the underling temporal fascia. This latter point ensures that the dissection is beneath the level of the temporoparietal fascia which is a continuation of the galea beneath the level of the temporal line, and is important as the temporal branch of the facial nerve runs either on its deep surface or within it. Damage to this branch of the facial nerve results in weakness of the forehead and partial ptosis due to loss of innervation to the frontalis, corrugator, procerus and occasionally a portion of the orbicularis oculi.

Flap elevation proceeds easily in the subgaleal layer by maintaining tension on the skin flap with skin hooks and Langenbeck retractors. Sharp-pronged retractors should be avoided as they lead to damage and bleeding from branches of the superficial temporal vessels on the surface of the coronal flap. Dissection proceeds using the sweeping action of a No. 10 scalpel blade or use of a ceramic monopolar diathermy blade, the latter having the advantage of reducing further blood loss. As the flap is freed, tension laterally is dealt with by incising the superficial layer of the superficial temporal fascia, paying regard to the temporal branch of the facial nerve. As the flap is dissected inferiorly and anteriorly, an incision is made in the superficial temporal facia at an angulation of 45° from a point 2.5 cm above the superior aspect of the lateral orbital margin, to a point at the base of the zygomatic arch. This incision is best performed with a No. 15 scalpel blade midway along this line approximately 3–4 cm above the body of the zygoma. Having made the incision, the yellow colour of the superficial temporal fat pad is seen separating the superficial and deep layers of the temporal fascia. The incision is now extended superiorly to the temporal line and inferiorly to the zygomatic arch with dissecting scissors (Figure 59.9). The next stage to help reflect the flap further inferiorly is to decide at what level the pericranium should be incised. If an anteriorly based flap is required then the pericranium may be incised posteriorly using cutting diathermy just above the superior temporal line from a point marked from the superior aspect of the incised superficial temporal fascia. The extent of the posterior dissection of the flap should be enough to allow sufficient length of this flap to cover any base of skull defect without tension (Figure 59.10). Alternatively, if the viability of an anteriorly based flap is in question due to trauma, then two laterally based flaps may be raised with the blood supply coming from the lateral aspect (Figure 59.11). In either case, sharp subperiosteal dissection allows reflection of the flap inferiorly to the superior and lateral orbital margins. At this juncture, the surpraorbital neurovascular bundles will be encountered. In a proportion of cases, simple subperiosteal dissection will allow the bundle to be displaced inferiorly. If there is a true foramen, the bundle may be freed by inserting the tip of a 5-mm fine osteotome into the foramen and hit inferiorly along already marked out triangular bone cuts. This usually delivers the inferior border of the foramen freeing the bundle (Figure 59.12).

Further subperiosteal dissection along the root of the nose may now proceed and may be aided by a vertical incision of the periostium on the undersurface of the flap, being careful not to attenuate the thickness of the skin flap. This permits dissection along the medial orbital rim to the level of the medial canthal tendon. The tendon's attachments should not be stripped of either its outer or inner insertions to the anterior and posterior lacrimal crests as this may lead to widening of the soft tissues across the nasal root and, in extreme cases, may induce telecanthus.

Laterally having now incised through the superficial temporal fascia and joined this superiorly with the reflected pericranium, the flap may be dissected more inferiorly by stripping of the lateral body of the zygoma and incising through the periosteum of the superior aspect of the zygomatic arch and posterior zygomatic body. Reflection of the flap exposes the body and arch of the zygoma leaving behind the superficial temporal fat pad intact. The temporal branch of the facial nerve is retracted in the flap beneath the reflected superficial temporal fascia.

Finally, depending on the access required, the skin flap may be mobilized still further by extension in the pre-auricular skin crease, thus permitting full exposure of the root of the zygomatic arch. Full subperiosteal orbital dissection is now possible mobilizing the attachment of the lateral canthal tendon and medially by identifying the anterior and posterior ethmoidal vessels. The ethmoidal vessels emerge at the level of the cribriform plate. The anterior and posterior vessels being 24 and 36 mm from the anterior lacrimal crest and the latter being 3–5 mm anterior to the optic foramen. Occasionally, very large facial lacerations may have

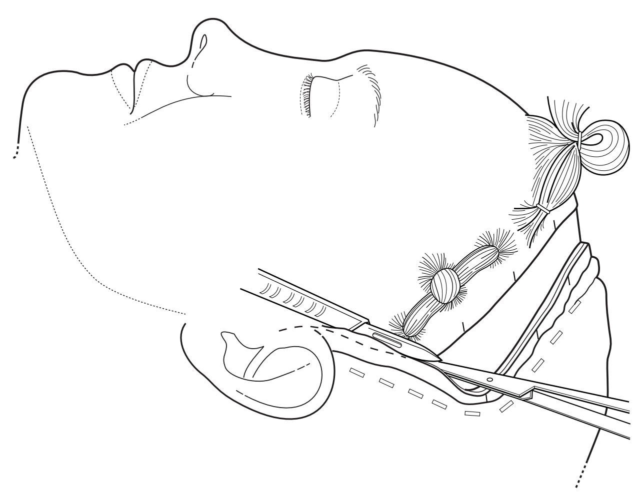
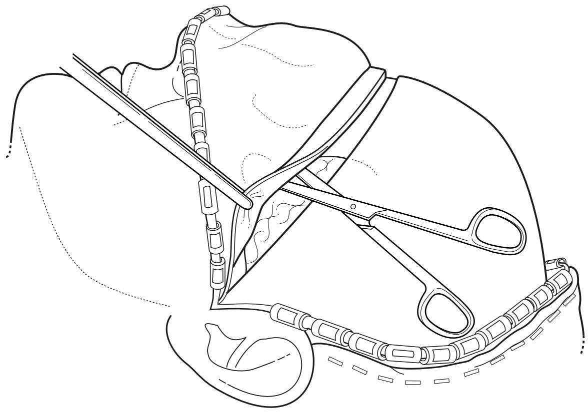
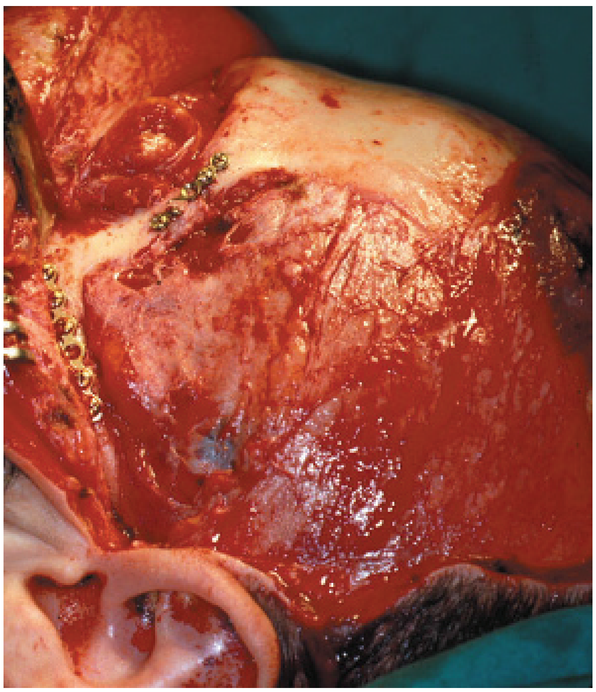


Figure 59.8 Development of coronal flap inferiorly.



(a)



(b)

Figure 59.9 The incision of the superficial temporal fascia.

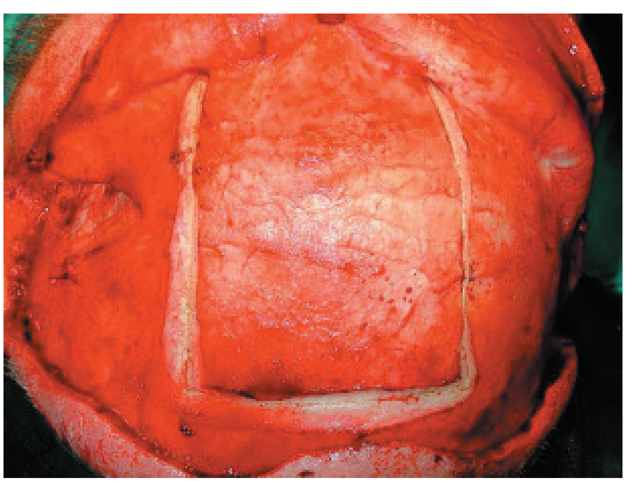
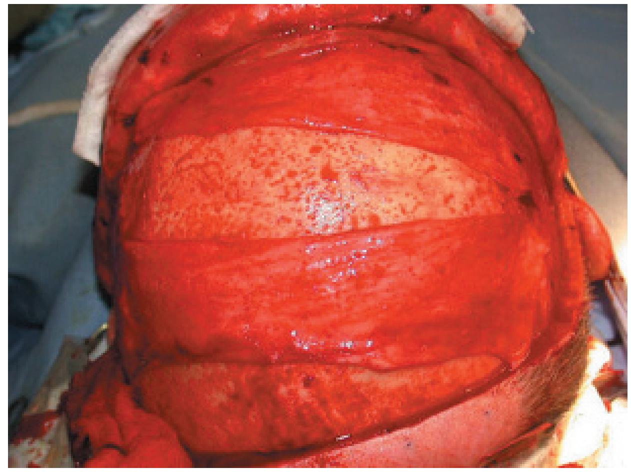


Figure 59.10 Anteriorly based peri-cranial flap.



(a)

(b)

Figure 59.11 Laterally based peri-cranial flap.

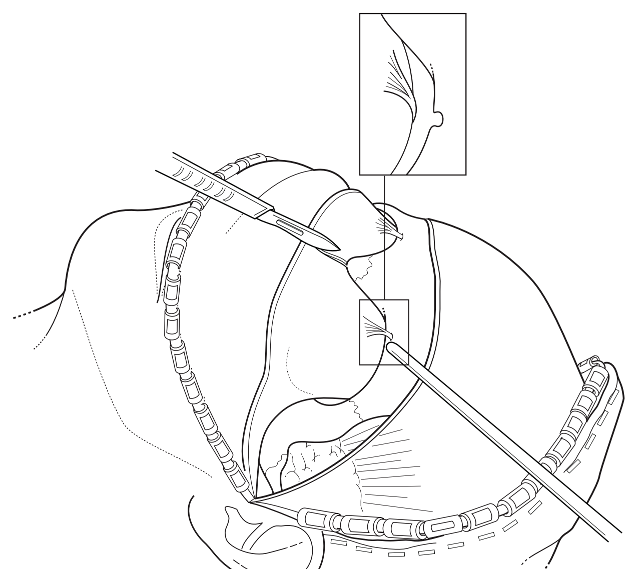


Figure 59.12 Release of supraorbital neurovascular bundle.

to be incorporated into the line of the incision so as not to risk the vascularity of the flap. Lacerations by themselves, however, offer poor access and may compromise treatment by restricting the size of craniotomy that may be achieved, and for this reason, unless exceptionally large, extension of lacerations is to be avoided.

Having achieved retraction of the flap, the craniotomy must now be planned and again the paramount concern is adequate access to effect intra-cranial inspection and dural repair if necessary. This will depend on the site of injury and suggested craniotomies are shown for central, lateral and complex injuries as described by Burnstein. Burr holes should be placed to minimize subsequent aesthetic problems and also in a position that will allow a good, low frontal craniotomy to deal with the frontal sinus, but also minimize the amount of brain retraction needed to explore the sub-basal region for dural repair and inspection of fractures of the orbital roof and anterior fossa floor. For this reason, burr holes may be placed laterally in the region of the pterion after reflection of the temporalis muscle in this region. Not only does this permit good low access to the horizontal cut of the craniotomy, but may be covered with temporalis at the end of the procedure reducing visible defects in the bone. The craniotomy is raised using a combination of large burs with or without a cut out clutch to perforate the skull without damaging the dura. Depending on the size of the flap required, further bur holes are required superiorly and possibly adjacent to the midline to help mobilize the flap with a side cutting and end guarded craniotome, to avoid damage to the dura and if the midline has to be crossed, then the sagittal sinus. Finally, the bone flap is raised using blunt dissection from the underlying dura. Exposure should now permit easy tension-free retraction of the frontal lobes and allow inspection of the anterior and posterior walls of the frontal sinus, orbital roof and cribriform regions (Figure 59.13).

If there are sub-basal dural lacerations, retraction may already have been facilitated by loss of CSF; alternatively, an osteotomy of the frontal bandeau may further aid access (Figure 59.14). A planned dural incision allows basal dural lacerations to be approached with minimal brain retraction, especially of the basal region, without damage to the olfactory tracts (Figure 59.15).

The next stage is to repair the frontal bandeau to restore frontal projection, width and height. This is closely linked to reductions in the temporal and zygomatic arch regions. Not only does reduction of these fractures form the basis for the accurate reposition of the mid-facial structures, but permits the size of defects of the orbital roof to be gauged and whether or not primary bone grafting is required.

If bone grafting is required, this is best performed now as use of any peri-cranial flap will preclude further bone work.

Bone grafts may be obtained by harvesting the inner table of the craniotomy segment. The cortices may be split initially using a fissure burr to define the plane between them, and the split is completed using a reciprocating saw and flexible osteotomes. The outer cortex may then be replaced over the donor site and the inner cortex used for grafting (Figure 59.16).

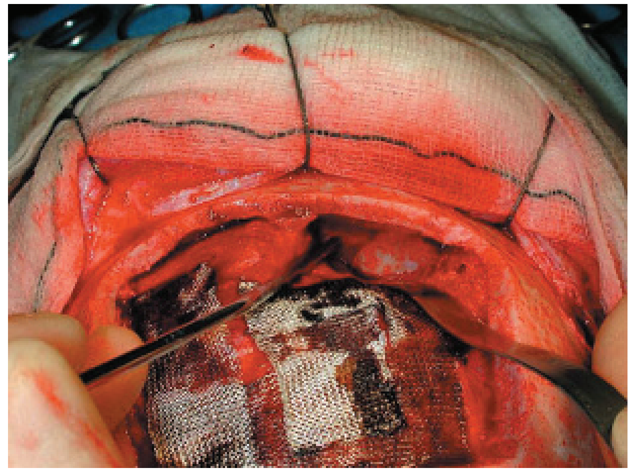


Figure 59.13 Retraction of frontal lobes.

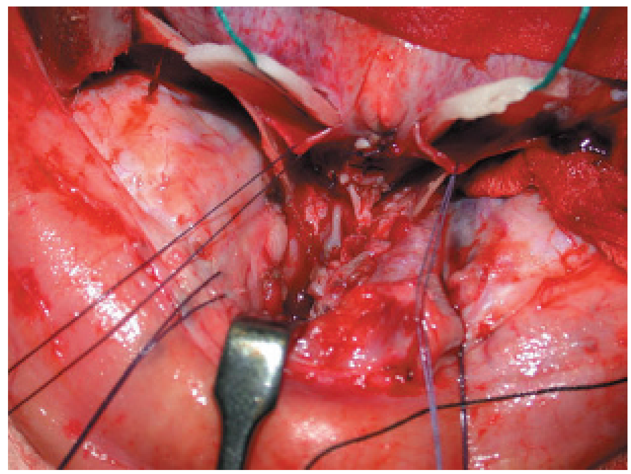


Figure 59.14 Temporary osteotomy of frontal bandeau.

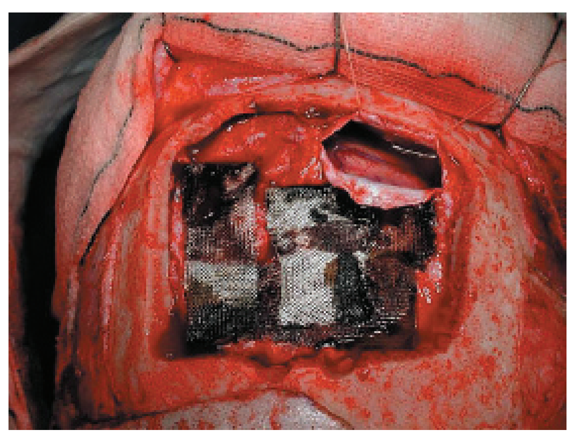


Figure 59.15 Intra-dural approach to basal region.

Outer cortical grafts may be obtained from the temporoparietal region overlying the non-dominant hemisphere. The size of the graft can be outlined with a fissure burr, used side on to cut through the outer cortex and the bone immediately outside the segment may be reduced in

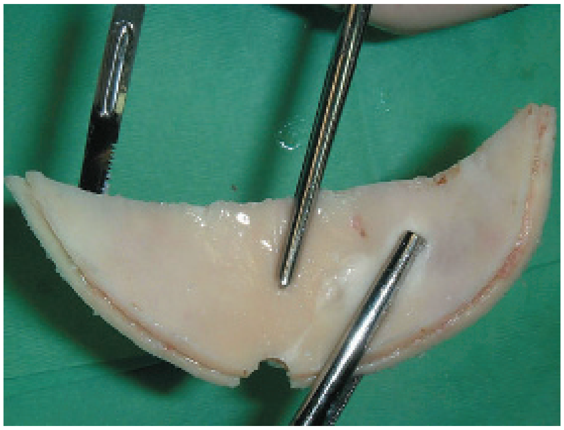


Figure 59.16 Craniotomy splitting with fine saw.

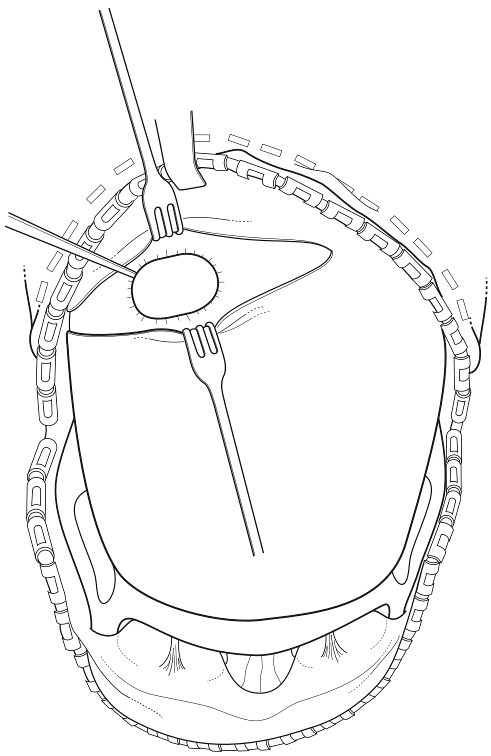


Figure 59.17 Harvesting outer table calvarial graft.

height using an acrylic burr. A slim osteotome can then be introduced into the diploic space and the graft harvested. Bleeding is arrested with a resorbable haemostatic agents which gives some bulk to the haematoma which can then be redraped with the periosteum to help minimize the subsequent depression (Figure 59.17).

The selection of osteosynthesis material requires maintenance of the reduced fractures and bone grafts in a stable position. Usually, titanium plates with a low profile utilizing screws 1–1.3 mm in diameter are used. This is sufficient as the bone is not load-bearing other than to withstand the pulsation of the dura or in the case of the orbital roof the weight of the frontal lobes. Bone grafts must take into account the original anatomy of the defect and nowhere is this more important than in restoring the upward curving nature of the orbital roof, failure to realize this important point may result in vertical hypoglobus and potentially exophthalmos. Bone grafting within the orbital roof is important to separate the pulsation of the brain from the orbital contents which may result in very unsightly pulsation of the eye. Having restored the orbital roof, the anterior fossa floor and if necessary cranialization of the frontal sinus, then vascularized peri-cranial grafts may now be introduced. If an anterior flap is raised, this may be fed in beneath the frontal lobes and be secured with a few sutures and supplemented with fibrin glue to try and obtain a watertight seal and close off the nasopharynx from the anterior fossa. If damage to the pericranium anteriorly has necessitated a laterally based flap, then this may be introduced from the region of the lateral craniotomy cut and burr hole. Finally, the craniotomy segment may be repositioned taking care not to compress the peri-cranial graft and trying to position any subsequent space in the bone cuts to give the most cosmetically acceptable result.

CLOSURE

A good closure will help achieve the correct soft tissue suspension over the anatomical hard tissue repair, failure to do so will result in gravity allowing the extensively mobilized tissue to move 'south'. This may be achieved in a number of ways. First, non-resorbable sutures are used to accurately attach the lateral canthal tendon and peri-orbita to fine drill holes positioned around the orbital aperture. This is combined with suspension sutures inserted into the periosteum overlying the zygomatic body and sutured to the temporal edge of the incised superior margin of the superficial temporal fascia. The temporalis must be replaced over the burr hole in the temporal region and bone dust kept from the original access may be used in any residual bone defects. Finally, the inferior aspect of the incised superficial temporal fascia is attached to the temporal fascia at a slightly higher level, to help further support the soft tissue drape of the face (Figure 59.18). A drain is placed beneath the flap with the inferior aspect reaching into

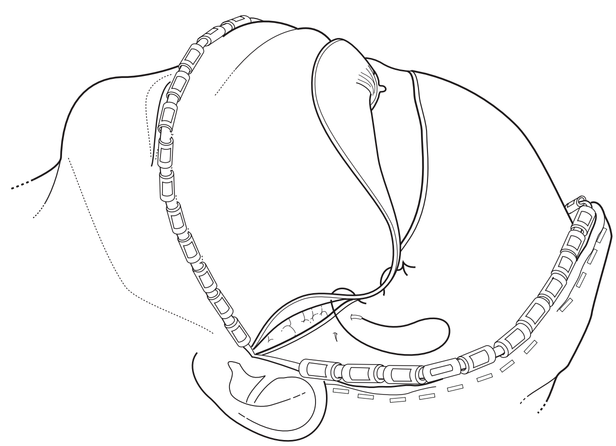


Figure 59.18 Temporal fascia closure.

the side having undergone the most extensive dissection to avoid collection in this region. A system with variable amounts of suction is ideal as leakage of CSF may require use of drains on gravity suction only. If CSF leakage is a real concern, then placement of a lumbar drain for a period of 5–7 days is favoured by some to allow time for the dural repair to establish itself. The scalp is closed with 2/0 resorbable suture, care being taken to use only the galea which allows for good soft tissue support and apposition of the wound margin.

In the region beneath the temporal line, more superficial sutures may be required and closure may be helped by removal of the staples placed initially to secure the drapes thus releasing tension from the posterior skin flap. Accurate positioning of the scalp is ensured by aligning the tattoo marks inserted at the beginning of the procedure. Skin closure is achieved very easily with staples ensuring that the wound margins are everted. A well-fitting head bandage is placed, making sure to cover the wound in the first instance with a non-adherent dressing and then absorbent swabs and finally cotton wool across the forehead and behind the ears before fitting a well-placed crepe bandage under tension. The cotton wool and avoidance of excessive tension in the dressing avoid pressure necrosis, particularly overlying the drain and forehead regions. The drain is secured only with tape to the head dressing allowing its removal when required without the need to disturb the head dressing thus helping to prevent further fluid accumulation which may lead to increased risk of infection and fibrosis.

POST-OPERATIVE CARE

The patient will be managed post-operatively in the neurosurgical high-dependency unit. The decision to extubate at the end of the procedure will have been discussed previously with the anaesthetist, but occasionally due to intra-operative considerations, such as frontal lobe manipulation, CSF leakage and positioning of a spinal drain, blood loss and temperature control, a short period of maintained intubation may be advisable before extubation. If a tracheostomy is present it is not a concern, but if the patient has had other forms of intubation, discussions over tube switching and acceptance of the tube post-surgery and in the weaning process will need to be decided upon. Antibiotics are usually continued for at least three post-operative doses and depending on the anterior fossa and dural repairs, as well as CSF leakage, it may be extended for several days.

MANAGEMENT OF THE FRONTAL SINUS

The treatment of the frontal sinus is controversial, not least of all as prospective studies in this area are few and most algorithms relate to the retrospective analysis of a unit's data over many years. There is a problem as studies certainly have shown complications many years after the original treatment, often presenting in other centres where the original treatment details are not known. It is safe to assume that one unit's complications may well be treated by another unit due to the time scales involved. Nonetheless, there has been a consensus about what one is hoping to achieve, namely a 'safe sinus' with the least intervention necessary. The frontal sinus is of variable size and is lined by respiratory epithelium that communicates via the frontonasal duct with the middle meatus of the nose. The duct is again in a variable structure, being well defined in some instances, but in more than 60% of cases achieves its drainage via communication with the ethmoidal air cells (Figure 59.19).

Frontal sinus fractures occur in approximately 2%–15% of facial fractures and are far more associated with craniofacial fractures involving the skull base, but may occur in isolation involving either the anterior wall, posterior wall or floor with associated duct injuries (Figure 59.20). While there may be obvious cosmetic concerns with depression of the anterior wall of the frontal sinus, it is the functional problems including chronic sinusitis (up to 60%), meningitis (6%) and also mucopyocele, osteomyelitis and cerebral abscess formation that dictate the need for treatment.

Undisplaced anterior wall fractures may require no treatment; however, if displaced, access is achieved along the lines described previously as for craniofacial fractures only differing in the amount of exposure that is necessary limiting exposure to between the superficial temporal lines, reducing the risk to the facial nerve. If the anterior wall is depressed, then it may be elevated without removal of the bone by placing 2-mm screws into the main fragments and elevated using forceps and subsequently immobilized with low profile 1.3 mm or similar titanium systems (Figure 59.21).

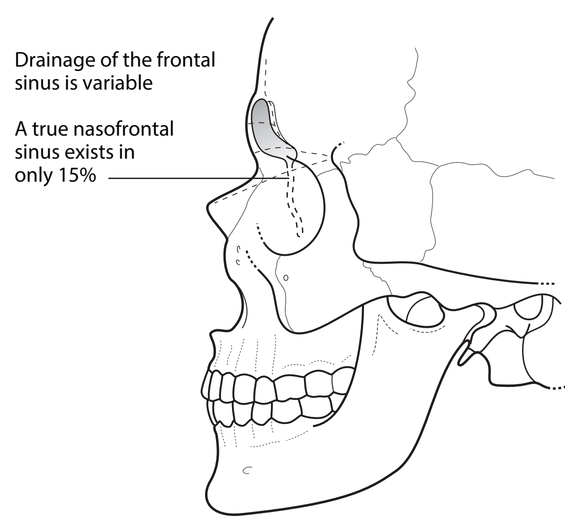


Figure 59.19 Anatomy of the frontal sinus and nasofrontal duct. The frontal sinus is a pyramidal, air-filled cavity lying within the lamina of the frontal bone creating an anterior and posterior wall to the sinus. Drainage of the frontal sinus is variable. A true nasofrontal duct exists in only 15%.

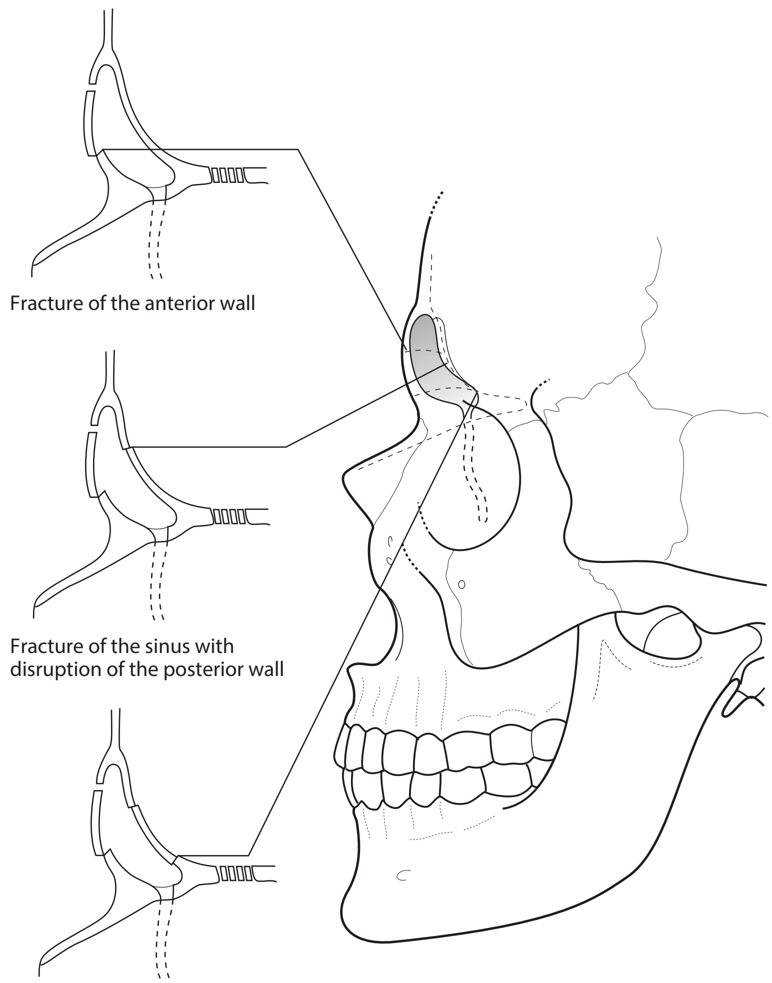


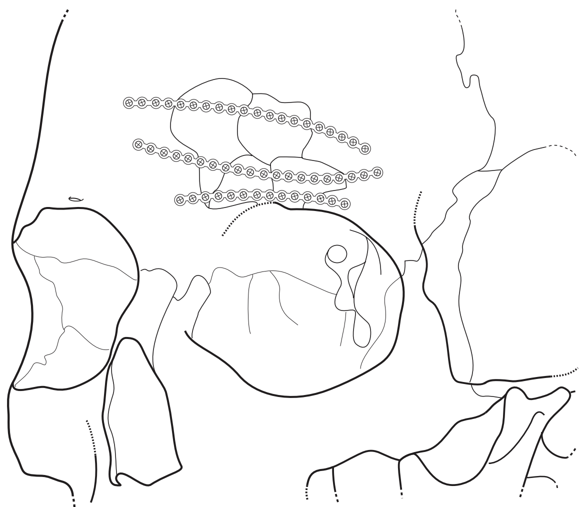
Figure 59.20 Classification of frontal sinus fractures.

If fractures are more depressed, then the fragments will have to be temporarily removed and accurately laid out on a moist swab in the same orientation, to assist in their accurate reassembly and subsequent insertion. Any necrotic or damaged lining may then be removed carefully leaving all viable mucosa. The remaining mucosa will help seed subsequent re-epithelialization of the repaired sinus. If defects have occurred, then calvarial grafts may be harvested as previously described and immobilized. If, after elevation of the bone fragments, they appear not to fit, it may be necessary to trim the bone margins to allow an accurate placement without overlap. This latter point results from the deformation of the bone segments during the fracture process.

Fractures of the frontal sinus floor may result in damage to the frontonasal duct which may subsequently lead to obstruction with mucocele formation. Stenting of the ducts has been shown to be associated with long-term stenosis, the author prefers, therefore, to seal off the frontonasal duct in such circumstances. The procedure involves the temporary removal of the anterior sinus wall, but in this instance all the mucosal lining is removed meticulously and the surface of the bone ground down with an acrylic burr to try and assure removal of all crypts of mucosa. The mucosa of the nasofrontal duct is mobilized and inverted through the infundibulum. Oxidized cellulose is then placed across and the defect is then filled with autogenous bone. The volume required may be large and, in some instances, iliac crest grafts may have to be utilized rather than morcellized calvarial grafts. Abdominal fat is to be avoided due to the variable levels of resorption and potential subsequent mucocele formation. The anterior wall may then be replaced and immobilized as previously described (Figure 59.22).

Isolated fractures of the posterior wall if displaced by more than 5 mm have been shown to be associated with dural lacerations and such fractures associated with a CSF leak should undergo cranialization. The technique utilizes the same exposure as before, but in this case following the low craniotomy, the posterior wall of the frontal sinus is removed, allowing all the frontal mucosa to be removed. The duct mucosa is inverted, as previously described, and covered with oxidized cellulose and this time a disc of cortical bone is placed over the duct orifice, and bone dust and milled bone obtained from the posterior wall is packed

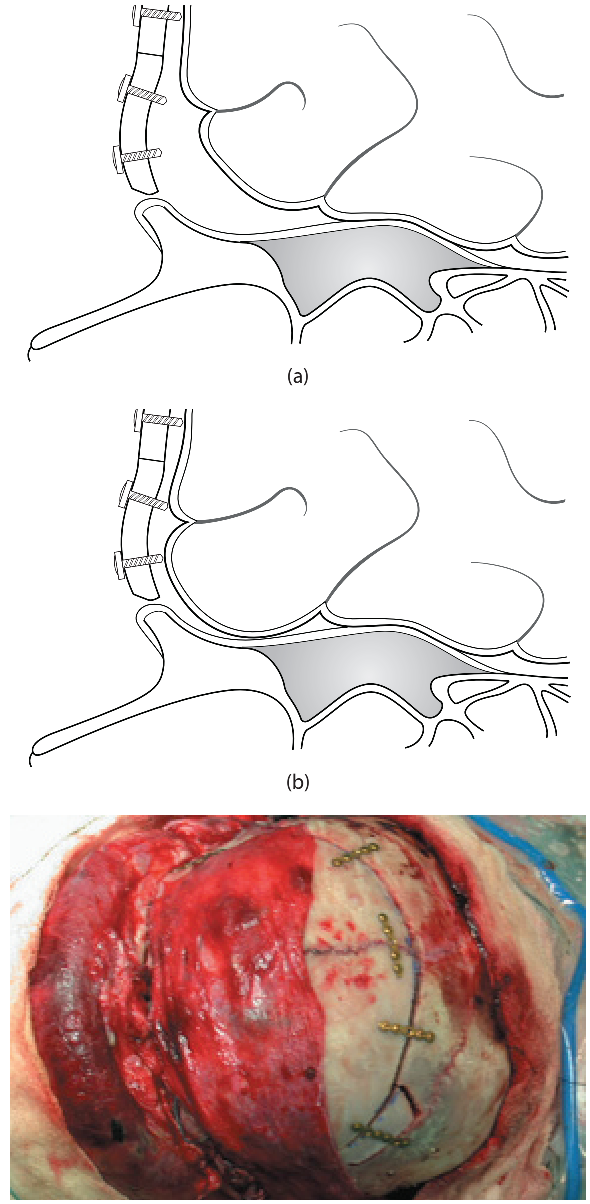
above it (Figure 59.23). A vascularized peri-cranial flap is then placed across the infundibulum and bone grafts, so as to be supported beneath the frontal lobes with its vascularized surface against the bone graft. Any dural tears will have been repaired by this time, but if the tears are subbasal then an intra-dural repair may be performed with the periocranium being introduced through the dural incision to lie under the frontal lobe (Figure 59.23), before the flap is secured with fibrin glue to achieve a watertight seal. The risk of a CSF leak may be further reduced by suturing the incised dural margin to the peri-cranial flap, but care has to be taken not to damage the vascularity of the graft. Closure is performed as described earlier in this section.



Undisplaced fractures of the anterior wall require no sugical intervention

Displaced fractures of the anterior wall should be reduced and fixed in the anatomical position to restore normal forehead contour

Figure 59.21 Reduction of anterior wall fracture of the frontal sinus.

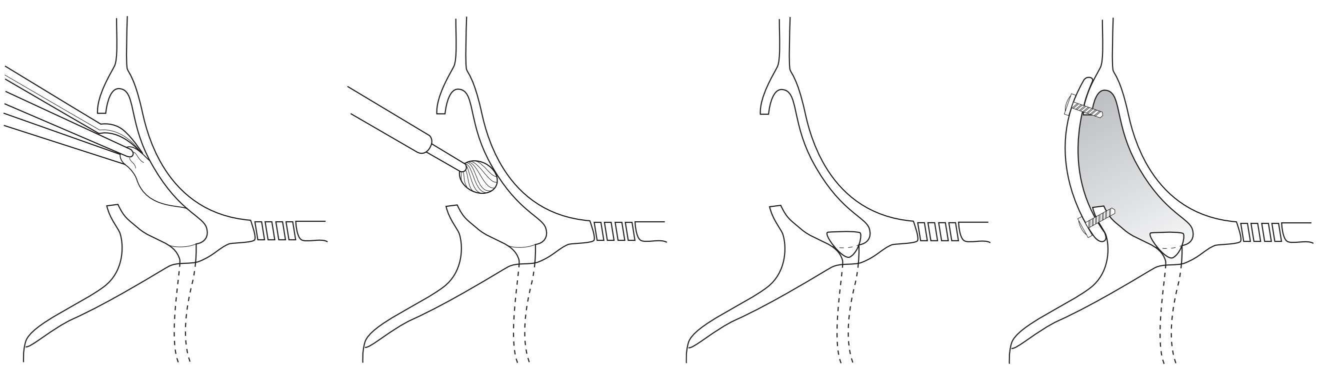


(a)

(b)

(c)

Figure 59.23 Frontal sinus cranilization.



(a) (b) (c) (d)

Figure 59.22 Frontal sinus obliteration.

Recently, several authors have advocated the endoscopic repair of frontal sinus fractures and, while this is in the early stages, there is some promise in this minimally invasive technique in specific situations. The reader is referred to the relevant articles, which are cited in 'Suggested Readings' section for a review of this technique.

Complications

Infection

This may be immediate in the form of meningitis, brain abscess or subdural emphyema, often related to failure to debride and gain adequate closure. Treatment involves antibiotic treatment with broad spectrum cephalosporins and metronidazole, together with possible reoperation and removal of infected craniotomy segments to allow the infection to settle and delay reconstruction to a later date. Late infection may be associated with the presence of a mucocele due to an obstructed frontal sinus or CSF fistula that will need to be addressed. Mococele formation may complicate 10% of unrelated cases and require removal of the frontal sinus and formal cranialization to remove all the respiratory epithelium (Figure 59.24).

Cerebrospinal fluid fistulas

Fistulas are relatively rare in closed injuries affecting only 2%, which rises to 9% in open or penetrating head injuries. Suggested investigations involve fine cut coronal CT or T2-weighted magnetic resonance imaging (MRI) with contrast.

Cisternograms are more invasive and the use of fluorescein intrathecally combined with nasal endoscopy has been shown to be of benefit in defects which are difficult to identify.

(a)

(b)

(c)

Figure 59.24 Aetiology of mucocele formation. The risk of infection is linked to communication between the nasal cavity and dural tears via the frontal sinus. The aetiology of a mucocele appears to be related to obstruction of the nasofrontal duct in a diseased or injured frontal sinus.

NASOETHMOIDAL FRACTURES

Background

Nasoethmoidal fractures present several difficulties related not only to restoring the aesthetics of this region, but also the functional consequences related to the close proximity to the skull base and frontal sinus, the orbital contents, and walls and lacrimal apparatus. The force applied is well withstood by the stout bone of the orbital aperture, including the bone of the frontonasal buttress, but if anterior force overcomes this initial resistance then the pneumatized ethmoidal air cells and weak medial walls of the orbit offer little structural support and may become grossly disrupted in comparison to the greater resistance given by the anterior skull base and orbital apex, designed physiologically to help protect the brain and soft tissues of the orbital apex. The key to dealing with fractures in this region is understanding the relationship of the medial canthal tendon and its attachment to the so-called central fragment of the nasomaxillary complex and lacrimal bones. The medial canthal tendon attaches to the medial orbit by superficial and deep limbs attached to the anterior and posterior lacrimal crests, respectively. It is the medial extension of the upper and lower tarsi meeting, where the preseptal

muscles divide into deep and superficial heads. This point is marked by the puntae of the upper and lower canaliculi within the lid margins. From this point, the canaliculi extend behind the medial canthal tendon into the lacrimal sac. The anterior horizontal segment of the tendon is attached firmly to the anterior lacrimal crest and is stronger than the posterior limb which is attached to the posterior lacrimal crest and serves to hold the eyelids against the globe in a posterior fashion. It is this medial and posterior relationship that has to be reconfigured in injuries involving the medial canthal tendon if the palpebral shape is to remain unaltered and the tarsal plates are to be supported in close apposition to the surface of the globe, and avoid epipora.

Nasoethmoidal fractures come as a spectrum ranging from simple dislocation to those which involve a pattern involving the medial wall of the orbit, frontal sinus, skull base, ethmoidal air cells, orbital rim and nasal bones. This means, therefore, that depending on the severity, other injuries associated with the frontonasal duct, lacrimal apparatus and medial canthal tendon must be addressed and the aims of treatment must not only address the reduction of the fractures, but deal with these functional and aesthetic issues. A classification of these injuries has been described by Markowitz, depending on the relative displacement of the medial canthal tendon, as types 1–3 (Figure 59.25).

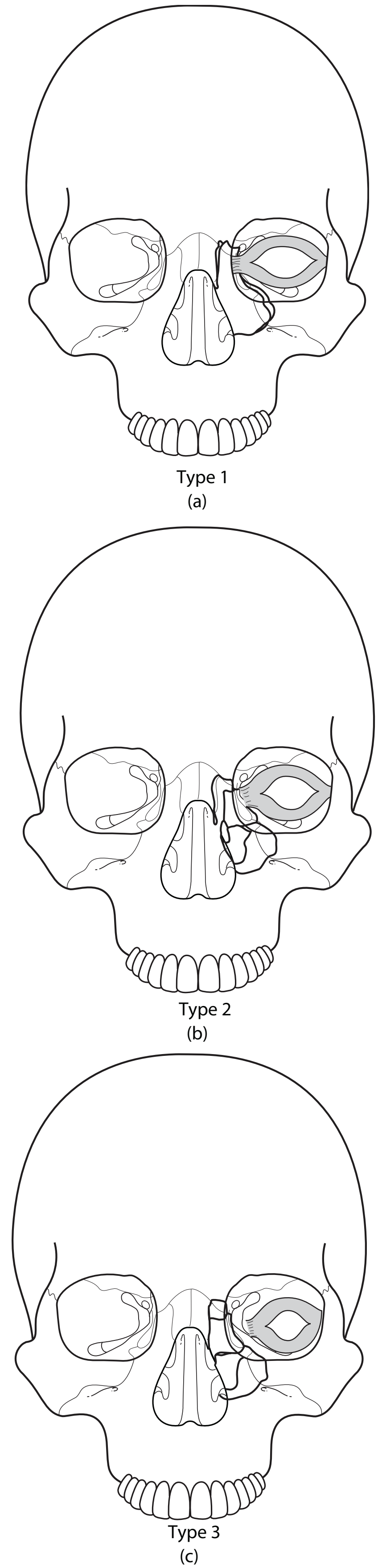


Figure 59.25 Classification of nasoethmodal fractures.

Sequencing of nasoethmoidal fractures

Sequencing follows the following pattern:

- Exposure
- Reduction and stabilization of the frontal bandeau and anterior fossa floor
- Restoration of the frontonasal angle
- Reconstruction of the outer orbital frame
- Repair of the medial orbital wall
- Reduction and fixation of midfacial buttresses
- Restoration of the medial canthal tendon
- Repair of the lacrimal system
- Closure
- Nasal plaster and septal splints

Exposure

Apart from simple undisplaced rim fractures, the approach of choice is the coronal flap modified to reach the nasal bridge by incising the periosteum over the nasal bridge, as previously described, care being taken to identify the lacrimal apparatus and medial canthal tendon. In addition, the approaches previously described within the orbital fracture section may be used to achieve adequate exposure.

Assuming the frontal bandeau is intact or has been repaired, the frontal nasal angle must be restored by reduction of the fracture and fixation with low profile 1–1.3-mm plates and screws and, if necessary, primary bone grafting

using split calvarium. It is important to ensure that the angle obtained is correct as significant shortening and posterior displacement can occur. This may mean slim osteotomes and spreaders being introduced to mobilize the fragments if impacted and especially if the fracture is more of a monobloc-type fracture than the more comminuted variety.

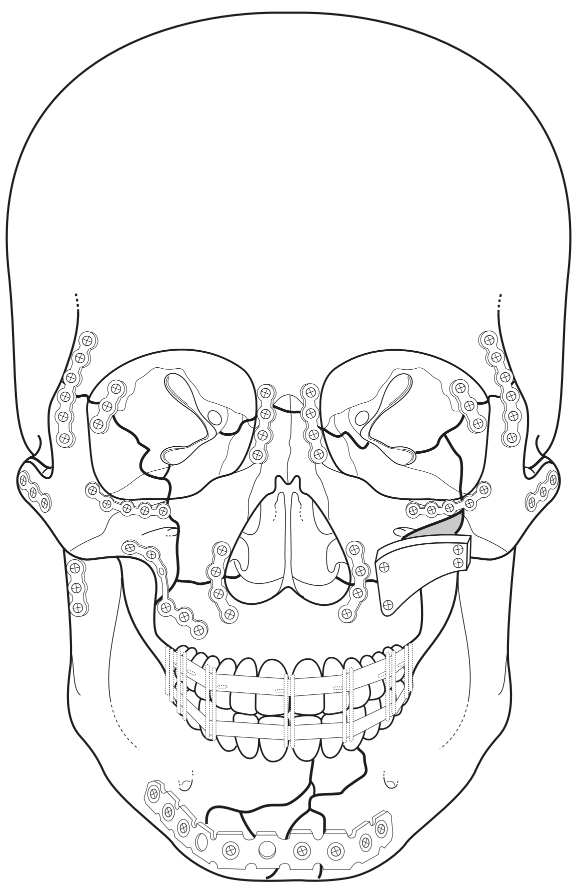
The lateral and inferior orbital wall may be approached via the coronal flap or adjuvant subciliary incisions so as to permit accurate alignment of the orbital margin taking care to use separate plates from above and below for fractures of the medial orbital rim, thus reducing excessive stripping of the anterior medial canthal tendon ligament which may lead to iatrogenic telecanthus and widening of the soft tissues across the bridge of the nose.

The alignment of the midfacial buttresses in the perialar and zygomatic regions via an intra-oral approach will help further with orientating the position of the maxilla and establish facial height, width and projection and aid accurate alignment of the nasoethmoidal complex (Figure 59.26).

Having stabilized the outer orbital and facial frames and frontonasal angle, the medial orbital wall defects may be repaired with adaptive conical-shaped titanium plates which can be placed from the subciliary approach and visualized from above beneath the coronal flap. It is easy for different surgical planes to be developed via both approaches and to aid plate insertion, a polydioxanone sheet passed from below into the medial orbital region can easily be seen from above defining the subperiosteal layer, acting as a soft tissue retractor. The plates may be secured along the orbital rim, but if plates have already been placed, then two or three screws placed into the inferior lateral aspect of the orbit in the sounder bone found here will suffice.

The medial canthal ligament in type 1 injuries will have already been stabilized by reduction of the fractures.

In type 2 and 3 injuries, however, there is usually the need to identify the ligament with the aid of a canthopexy wire. Specialized wires are available (Synthes, Welwyn Garden City, UK). A stainless steel needle is passed externally through the medial caruncular region emerging interiorly through the inner surface of the down-turned coronal flap through the identified medial canthal tendon. This latter point may be identified by grasping the area behind the lacrimal apparatus with toothed forceps and sequentially observing the effects on the medial canthal tendon. It must be remembered that the angulation of the medial canthal region and the adaption of the eyelids depend on good support of the eyelids by a medial canthal

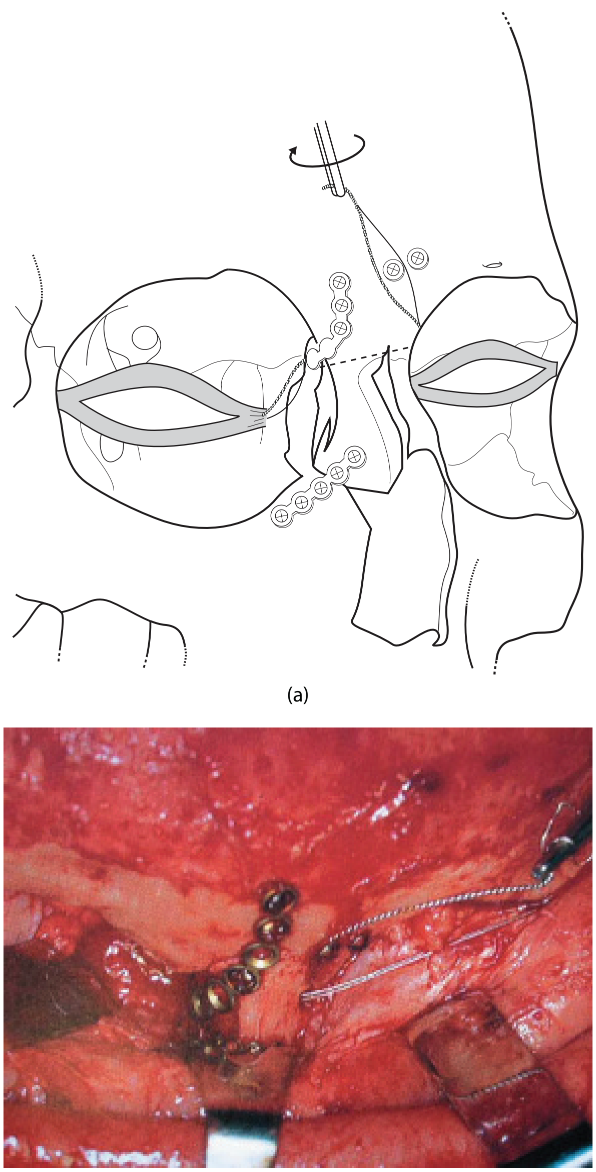


(a)

(b)

Figure 59.26 Reduction and alignment of midfacial buttresses.

tendon that is inserted superiorly and posteriorly. The best way to ensure this is to use a curved plate from the frontal region which may act as a point of support for the canthal insertion. In such cases, the tendon wire is passed through the lower hole of a suitable low profile plate. A passage for the needle is then made by drilling across the ethmoidal region behind the lacrimal apparatus to the contralateral side aiming slightly posteriorly. The use of a green needle will facilitate the passage of the wire's needle across the tract created. The curved plate may be so positioned and secured on the frontal bone to give support for the tendon insertion helping to restore the medial canthal angle, supporting the tarsal plates and addressing any telecanthus by tightening the wire to a superiorly placed screw (Figure 59.27).



(a)

(b)

Figure 59.27 Alignment of medial canthal tendon using tendon wire and medial orbital plate.

The lacrimal sac and duct must be closely inspected for damage. Many late obstructions of the system result from inadequate reduction of the fractures and blockages in the intra-bony part of the lacrimal system. Accurate fixation of the fractures will help this point. However, lacerations of the medial aspect of the lower eyelid carry significant risk of damage to the inferior canaliculus. If there is clear laceration in this region then identification of the severed ends may be cannulated with ophthalmic silastic stents, but it must be remembered that epiphora will not result if one of the canaliculi are present and functioning and if this is not easily achieved then such procedures are best left as injudicious attempts at passing catheters may cause damage to the remaining canaliculus. It may be that further dacryocystorhinostomy may be necessary even in those cases where the duct has been repaired, as stenosis may occur even in stents left in place for 6 months.

Complications

Aesthetic blunting and vertical discrepancies of the medial canthal tendon are best dealt with through a combination of osteotomy and reattachment of the tendon if necessary; this latter point depends on the angle of the medial canthus. In general terms, trying to shorten the tendon without addressing the widening of the bone will not correct the defect.

Epiphora should be investigated by an ophthalmic surgeon, usually with a dacryocystogram and either the duct repaired or, more likely, a dacryocystorhinostomy. Cerebral sinus thrombosis (CST), fistulas, infection and mucocoele formation associated with frontal duct injuries and anterior fossa floor injuries are dealt with as described above. A final complication involves orbital volume changes to the associated medial wall defects.

Top tips

- Treat these injuries as part of a multidisciplinary team in specialized centres.
- Identify and treat appropriately associated life-threatening injuries.
- Outline a clear team plan for operation and sequencing on operation board.
- Avoidance of facial nerve injury by division of superficial temporalis fascia.
- Mobilization of supraorbital bundle with osteotomes.
- Preservation of peri-cranial flaps.
- Accurate soft tissue resuspension following coronal flap.
- Use of orbital plate to help give support for insertion of medial canthal tendon.

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60

Zygomatic fractures

CHRIS VINALL and MICHAEL PERRY

CONTENTS

Terminology can be confusing. ‘Zygoma’, ‘malar’, ‘cheek’, ‘zygomaticomaxillary’, ‘zygomaticomaxillary orbital’, ‘tripod’ and ‘tetrapod’ are all terms used to describe essentially the same injury – a fracture of the zygomaticomaxillary orbital complex (Figure 60.1). Apart from isolated zygomatic arch fractures, nearly all other fractures involve part of the orbital floor and lateral orbital wall. Therefore, assessments of the orbit (and eye) are an integral part of management.

APPLIED ANATOMY

The cheek is predominantly formed by the zygomatic bone. This fuses with the frontal bone at the frontozygomatic (FZ) suture under the eyebrow, with the maxilla medially and with the temporal bone posteriorly and within the orbit. The body of the zygoma provides the aesthetic prominence of the cheek and together with the supraorbital ridge affords some protection to the eye. Superiorly, the body of the zygoma forms approximately the lateral two-thirds of the infraorbital rim, which is important for lower eyelid support. Consequently, any displacement in this area can affect eyelid function. Vertical displacement of the entire zygoma can lower the lateral canthus and lateral attachment of the globe with it (Whitnall’s tubercle). This can result in diplopia, hypoglobus and an anti-mongoloid slant to the eye (Figure 60.2).

The facial skeleton is not a solid structure, but contains several ‘cavities’, notably the sinuses, orbits and nasal cavity. Around these, the bones condense to form a series of vertical struts known as ‘buttresses’. The zygoma forms part of the lateral buttress. Horizontal buttresses also exist, but are much thinner. Consequently, the facial skeleton is very good at resisting vertically directed forces (biting/chewing), but is relatively weak at resisting horizontal forces (i.e. during most injuries). It has been suggested that sinuses have evolved to produce this survival advantage. Much like the chassis of a car, the face crumples, absorbing much of the kinetic energy during impact. The buttresses are a key element to facial repair and the support for any screws.

The temporalis muscle passes beneath the zygomatic arch to insert into the coronoid process of the mandible. Displaced fractures of the zygomatic arch can therefore impede mouth opening by interfering with this. The muscle is invested in the temporal fascia, which arises from the skull and passes down to insert into the zygomatic arch. This is an important surgical landmark (Gillies approach). The masseter muscle passes up from the mandible and attaches to the body of the zygoma and its arch. This may have a role in post-operative displacement of fractures which have not been internally (or externally) fixed. It is argued that fractures should be treated by open reduction and internal fixation (ORIF), as displacement may be caused by

masseteric pull over the ensuing weeks. Just because the bone is accurately reduced immediately after surgery, it does not mean that it will stay there.

The zygoma and maxilla support many of the periorbital and perinasal muscles attached to the periosteum. In extensive repairs, degloving of much of these bones may be required. Resuspension of the soft tissues is important during wound closure to prevent sagging post-operatively. The infraorbital nerve supplies sensation to the majority of the cheek and the ipsilateral half of the nose and upper lip. This passes along the floor of the orbit and exits the infraorbital foramen approximately 1 cm below the infraorbital rim, approximately midway along its length. The infraorbital canal and foramen form a plane of weakness and fractures often pass nearby. The nerve is at risk during repair.

ASSESSMENT

A number of classifications exist. A practical one would be to consider fractures as follows:

- Isolated
  - Zygomatic arch
  - Infraorbital rim
- Minimally displaced
- Displaced fractured
- Comminuted fractured
- Associated with midface or complex orbital fractures

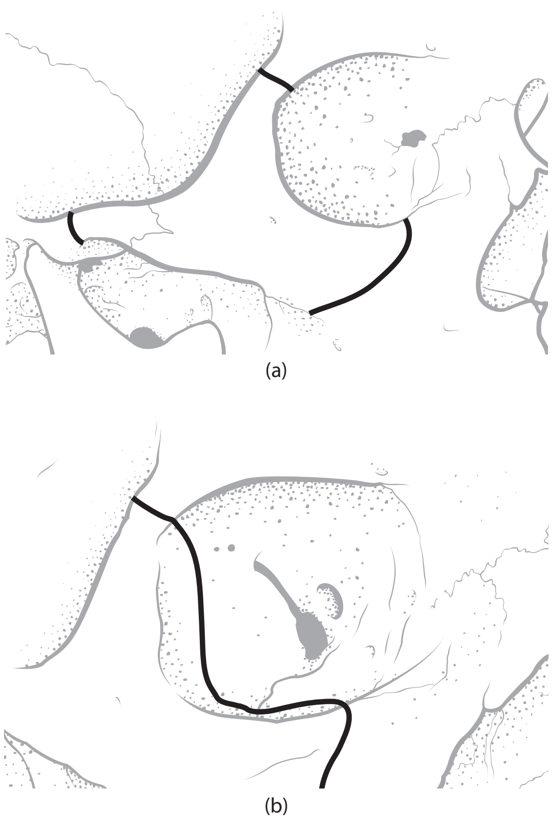


Figure 60.1 Fracture configuration.

With the exception of isolated arch fractures, all zygomatic fractures extend into the orbit. Following assessment of the head and neck (remember the ABCs [airway, breathing, circulation]), the eye therefore takes priority over any fractures. Check for ocular injury, diplopia and signs of entrapment. Clinical features of a fracture may include the following:

- Pain
- Periorbital bruising and swelling
- Limitation of eye movements with diplopia
- Altered sensation of cheek/upper lip
- Restricted jaw movements
- Subconjunctival haemorrhage and chemosis
- Surgical emphysema
- Flattening of the malar prominence (often masked by swelling immediately after injury)
- Palpable infraorbital step
- Anti-mongoloid slant
- Unilateral epistaxis (due to bleeding into the maxillary sinus)
- Enophthalmos
- Exophthalmos
- Hypoglobus (vertical ocular dystopia)
- Dysocclusion (premature contact on ipsilateral molar teeth, due to flexing of the upper dental arch)

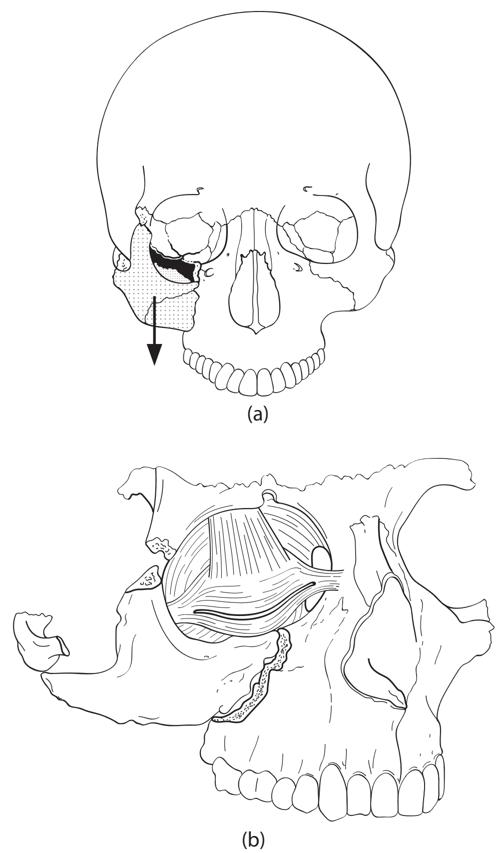


Figure 60.2 Downward displacement results in vertical ocular dystopia and an anti-mongoloid slant.

RADIOGRAPHS AND OTHER USEFUL INVESTIGATIONS

Investigations include the following:

- Visual acuity.
- Force duction test under local anaesthetic (should detect entrapment of orbital soft tissues).
- Comprehensive orthoptic assessment (not just a Hess chart).
- Plain radiographs – occipitomental (OM), lateral face and submental vertex (SMV). Look carefully – sometimes the only clue is a fluid level in the antrum.
- Computed tomography (CT) scan, both axial and coronal. These are increasingly used in patient evaluation. Indications include high-energy injuries (is the orbital apex involved?), suspected orbital floor involvement, comminuted or severely displaced fractures, other midface fractures suspected and assessment of the arch.
- Ultrasound has been reported as useful for detecting fractures, but is not commonly used.
- Maxillary sinus endoscopy for orbital floor fractures (not commonly used).

FIRST AID MEASURES

These fractures do not require urgent intervention and can be assessed as an outpatient. In the interim, patients should be advised not to blow their nose, in order to avoid surgical emphysema. The concern here is not the air, but the associated contamination (mucus, etc.), which can pass into the orbit and soft tissues of the cheek through the fracture. This can result in orbital cellulitis, both a sight- and life-threatening condition if untreated. Patients may also be advised not to fly, although there is no good evidence base for how long in the literature; the author's advice is for 3 weeks. Some units may prescribe prophylactic antibiotics.

INDICATIONS FOR REDUCTION AND TIMING OF SURGERY

When there is clinical and radiological evidence of a displaced zygomatic fracture, indications include the following:

- Facial deformity
- Loss of lower eyelid support
- Ocular dystopia
- Limitation of mandibular opening
- Sensory nerve deficit thought to be due to nerve compression

Timing of treatment depends on the degree of swelling and the general condition of the patient (notably any head or ocular injuries). Surgery does not need to be carried out on an emergency basis, although on occasion it can be undertaken 'immediately' (i.e. within a few days). However, significant swelling may interfere with accurate clinical assessment, both as an indication for treatment (do not just look at the x-ray) and an on-table assessment (is this adequately reduced?). It also makes aesthetic incision placement particularly difficult. Furthermore, swelling may be exacerbated by surgical manipulation, so care should be taken if there is any proptosis. Surgery is therefore often carried out either immediately or about 5–10 days following injury. In the author's experience, acceptable results can still be obtained up to 5 weeks after injury, but all the fractures need to be openly reduced, callus osteotomized and accurate reduction becomes much more difficult. This may be necessary only in exceptional circumstances.

REDUCTION AND REPAIR

This depends on the fracture configuration and the degree of displacement. In determining treatment, consider the following:

- How displaced is the fracture? Accept if minimal, to avoid risks of surgery (especially in medically compromised and those on aspirin/anticoagulants).
- Does the lateral buttress look comminuted on imaging? If so, some sort of fixation may be required to prevent collapse of the cheek. Do not use percutaneous hooks blindly – they may comminute this more.
- Is the zygomatic arch 'greensticked' or telescoped? The arch is important for cheek projection and may need to be reduced and aligned fully to maintain this. If telescoped, access to it for fixation may be required.
- Is the infraorbital rim comminuted? If so, it may need repair.
- Does the orbital floor also need exploration and/or repair(s) (see Chapter 58)?
- Is the FZ suture 'greensticked' or displaced? If displaced, this may need open reduction and repair.

If none of the above applies, a closed reduction may suffice. Case selection is very important both pre-operatively and 'on the table', to identify those patients which are unlikely to relapse post-operatively due to lack of any fixation. Closed reduction techniques include the following:

- Temporal approach (Gillies) (Figure 60.3)
- Percutaneous or 'malar' hook (sometimes referred to as 'Poswillo') (Figure 60.4)
- Eyebrow approach – zygomatic elevator
- Carroll–Girard screw (now more of historical importance)
- Intra-oral approaches (upper buccal sulcus) (Figure 60.5)

All of these involve making an incision somewhere on the patient and could therefore technically be argued as open techniques.

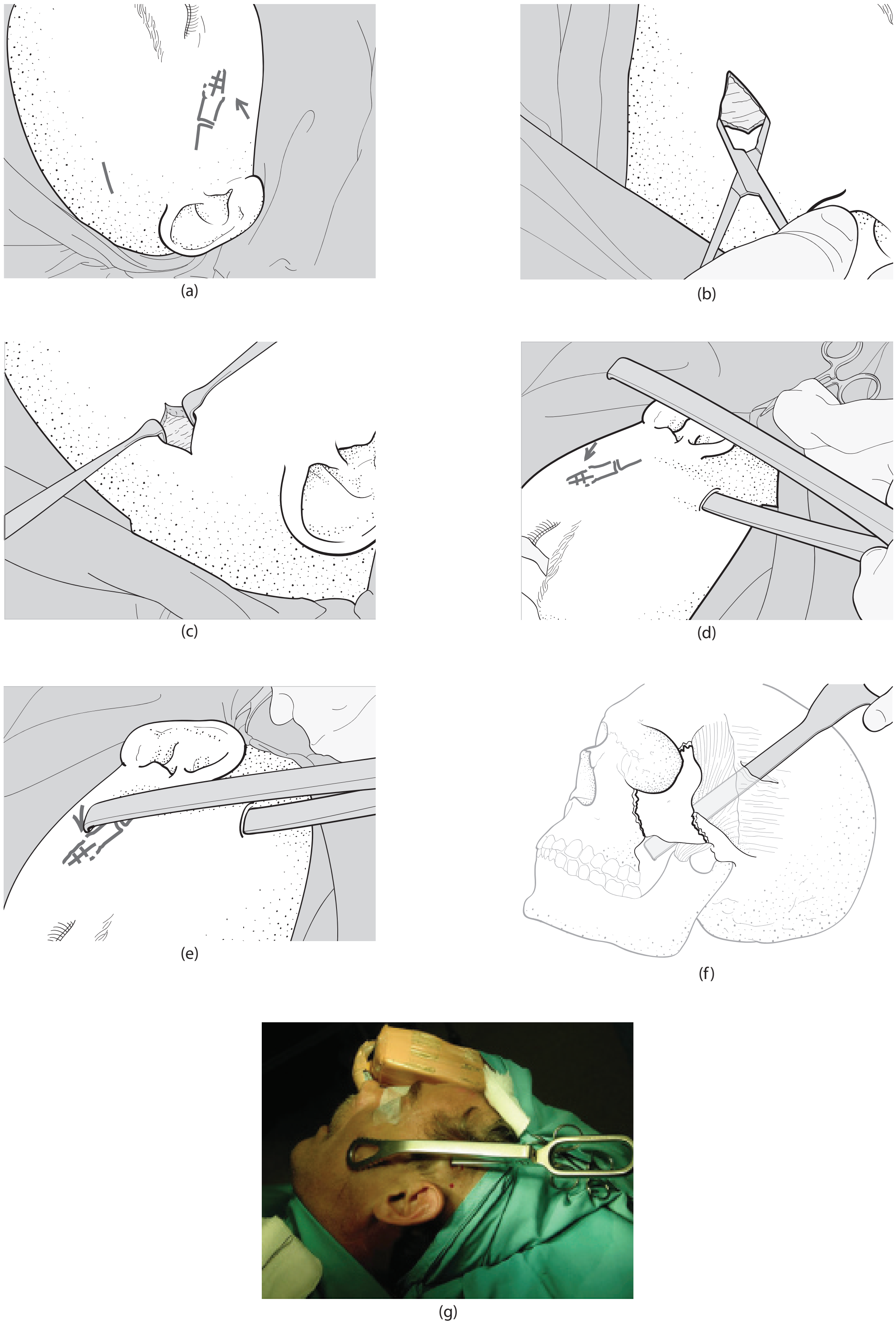


Figure 60.3 A Gillies lift. (a) Fracture site marked. 2-cm skin incision in the temple. (b) Following skin incision blunt dissect down to temporalis fascia (TF). Watch out for superficial temporal artery. (c) TF is incised and lifted off the temporalis muscle. A curved clip is good for this. (d) The elevator is passed deep to the TF towards the zygoma. Try passing a Howarth's periosteal elevator before – it helps open up the correct plane. (e) Make sure the elevator is under the bone before lifting (do not use the skull as a fulcrum). Schematic/operative view immediately prior to lift. (f) Surgical anatomy of lift.

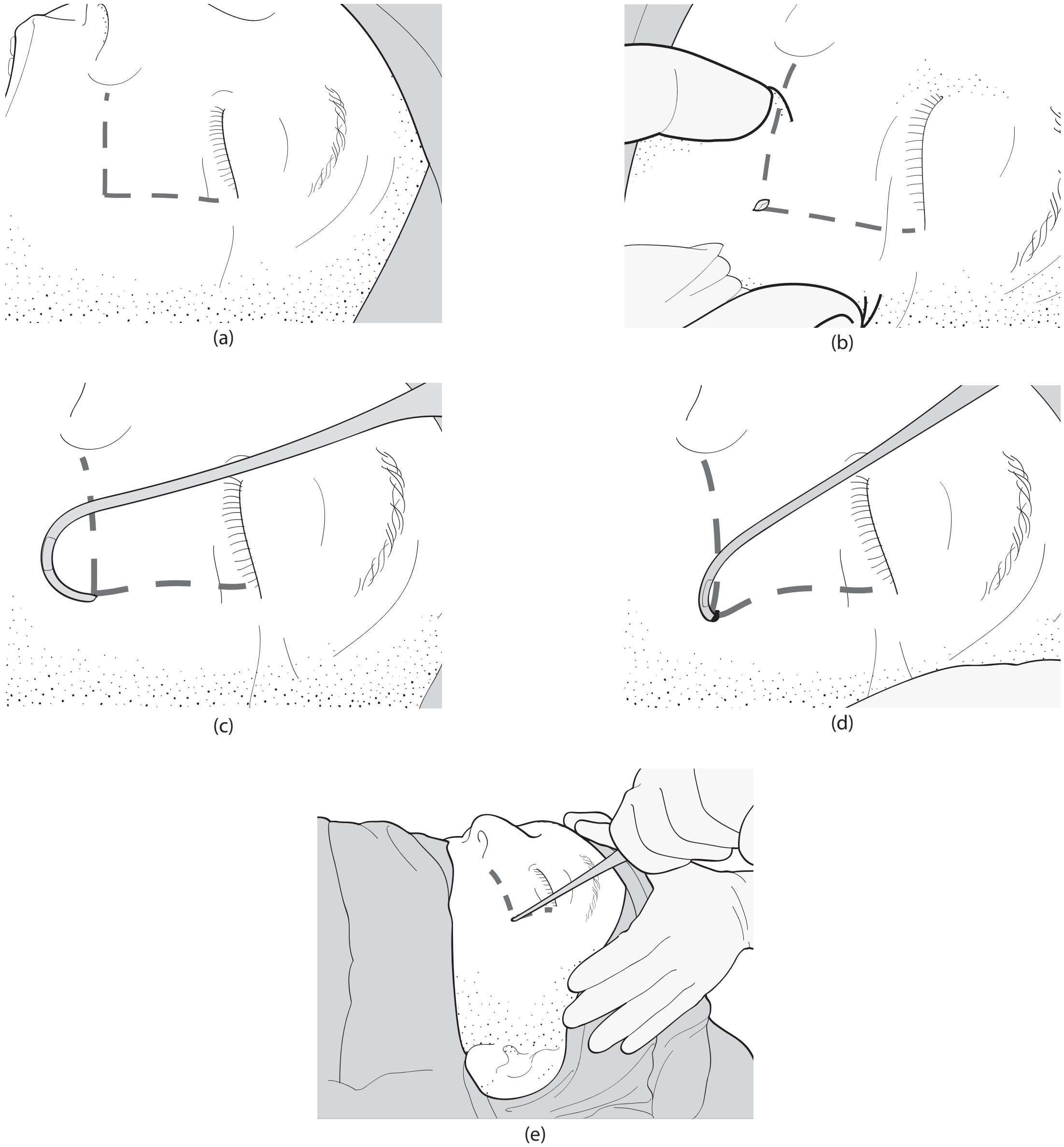


Figure 60.4 A malar hook. (a) Entry point marked. (b) Stab incision. (c) Hook introduced and rotated under malar bony prominence. (d) Carefully lift 'up and out'.

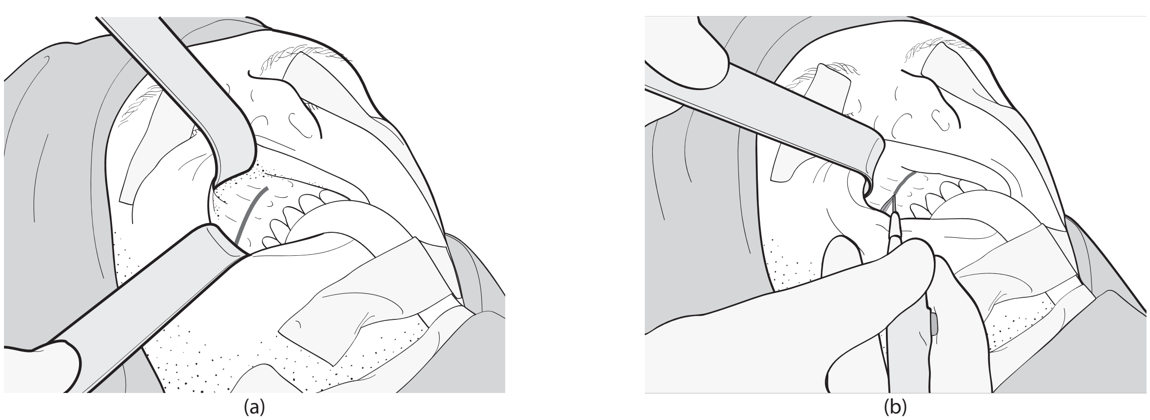


Figure 60.5 A buttress plate. (a) Mucosa marked allowing cuff to close. (b) Incision with knife or cutting diathermy (care with metal retractors).

(*Continued*)

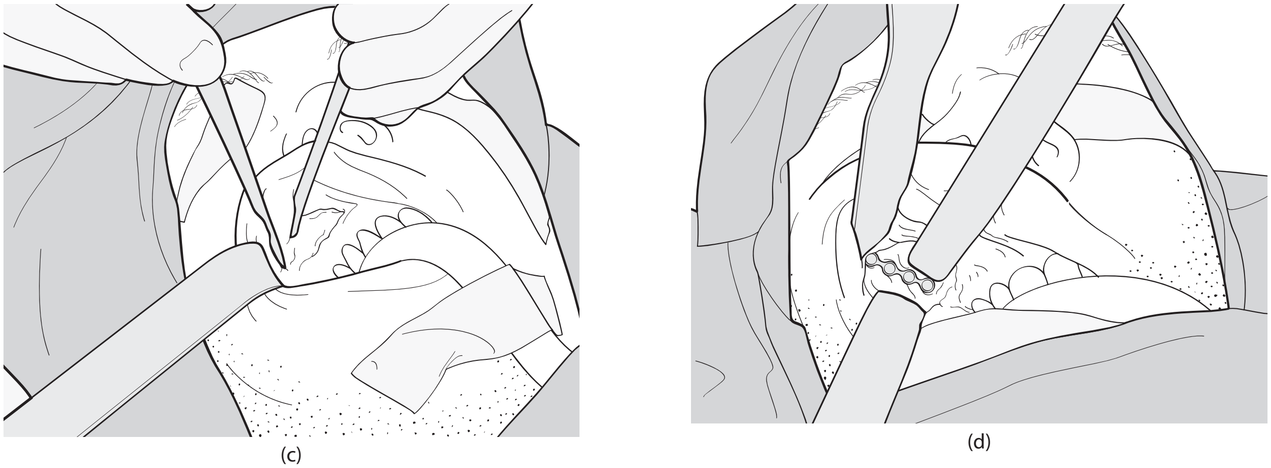


Figure 60.5 (*Continued*) (c) Subperiosteal dissection to expose fractures. (d) Following fracture reduction (Gillies, hook or via incision) ORIF with four-hole plate (usually).

More recently, there has been a general move towards ORIF, placing at least one plate (usually either a 'buttress' plate or one across the FZ suture). This is based on the concerns regarding masseteric and other forces acting on an unsupported reduction over the ensuing weeks. A buttress plate can be placed transorally and a FZ plate via a small upper blepharoplasty incision (Figure 60.6). In both cases, scarring is virtually invisible. However, this is still a matter of personal preference for each surgeon and closed techniques still have an important role to play in management. Exposure to the infraorbital rim should be avoided if at all possible. These scars may be more noticeable, contraction can distort the lower eyelid, there is a risk of injury to the infraorbital nerve and the fixation is the weakest of all the fracture sites. It may be necessary, however, to access the orbit and/or repair multiple rim fragments.

Sequencing is a matter of choice. This author's approach is generally as follows:

1. Address the FZ suture first, if it is significantly displaced. The purpose of the fixation is to re-establish the vertical height of the fracture and hopefully the correct height of the lateral canthal/Whitnall's attachments.
2. If necessary, reduce and repair the arch. This is only required occasionally and in significantly telescoped arches, but it does necessitate a posterior approach (pre-auricular or cutaneous incision). The arch is key to cheek projection. Careful assessment is necessary, even if not telescoped it may be bowed laterally and needs at least digital reduction.
3. Reduce and repair the lateral buttress. This is undertaken via an intra-oral approach. In many cases, this may be the only procedure required, if (1) and (2) are not significantly displaced. This plate provides mechanical stability.
4. Assess the infraorbital rim/orbital floor (force duction test) and expose if necessary.
5. Consider the need for bone grafting the buttress. This is rare and more likely in high-energy injuries.
6. Careful resuspension of the cheek prior to closure.

A step-wise approach is therefore needed and patients need to give informed consent appropriately. In many cases, either a closed approach or 'buttress' plate will suffice, usually the latter.

ISOLATED ARCH FRACTURES

These can often be reduced via a Gillies approach or transorally. They are usually stable, but occasionally can fall back down. If so, they may need support. Alternatives include the following:

- Accept this and deal with any problems secondarily
- Suturing an external splint along the arch (suture is passed deep to the arch and tied over the splint)
- Balloon inflation deep to the arch (a foley catheter will suffice)
- ORIF via a pre-auricular or overlying incision (beware the facial nerve)

OTHER FORM OF FIXATION

By and large, these are rare, since reduction and a simple buttress plate can be undertaken relatively quickly in many cases. External fixation (Figure 60.7), like the mandible, may have a small role to play. Alternatively the zygoma can be 'kebabed' using a trans-antral K-wire. This is certainly quick, but is a blind procedure with risks to both eyes if incorrectly performed.

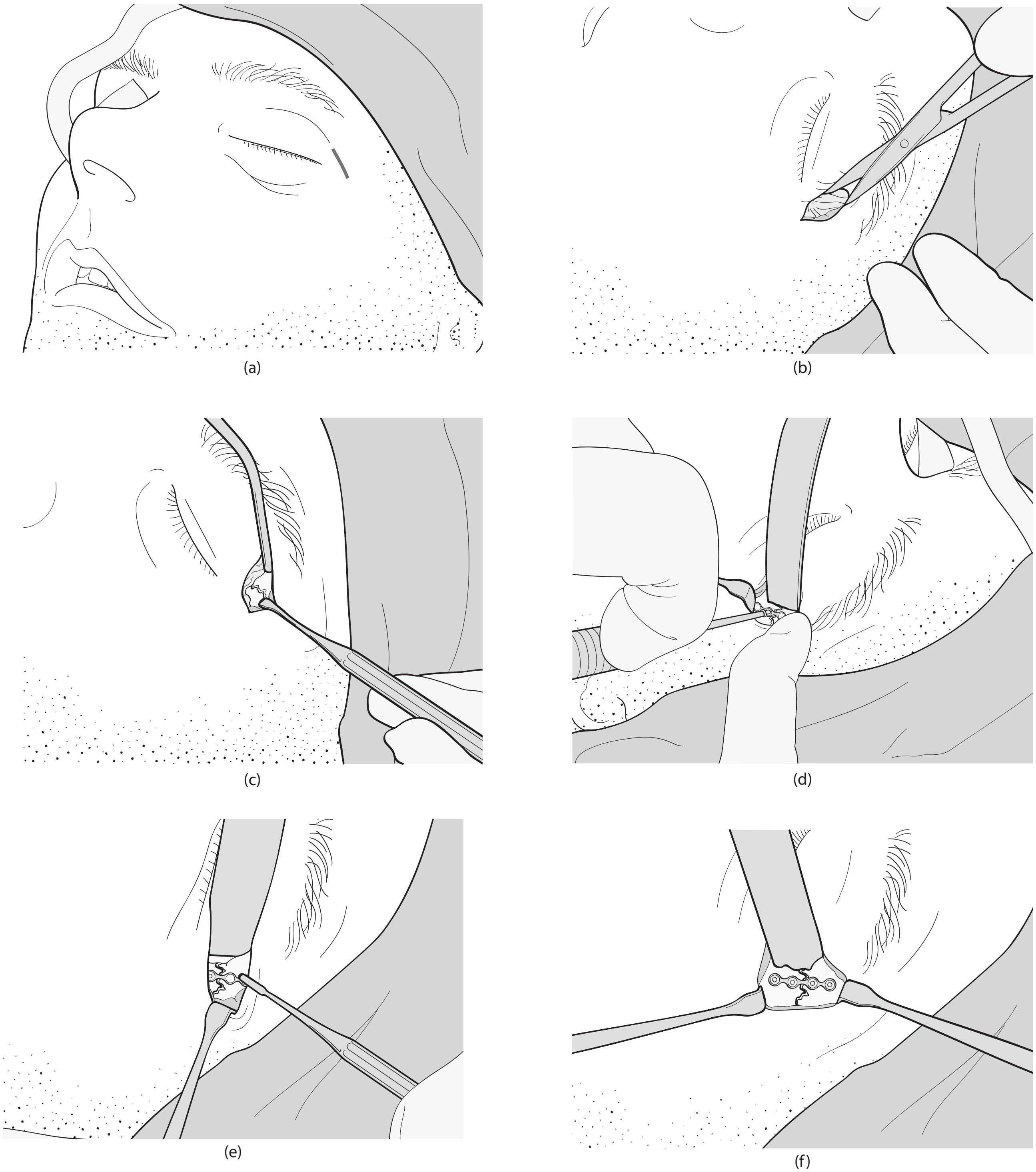
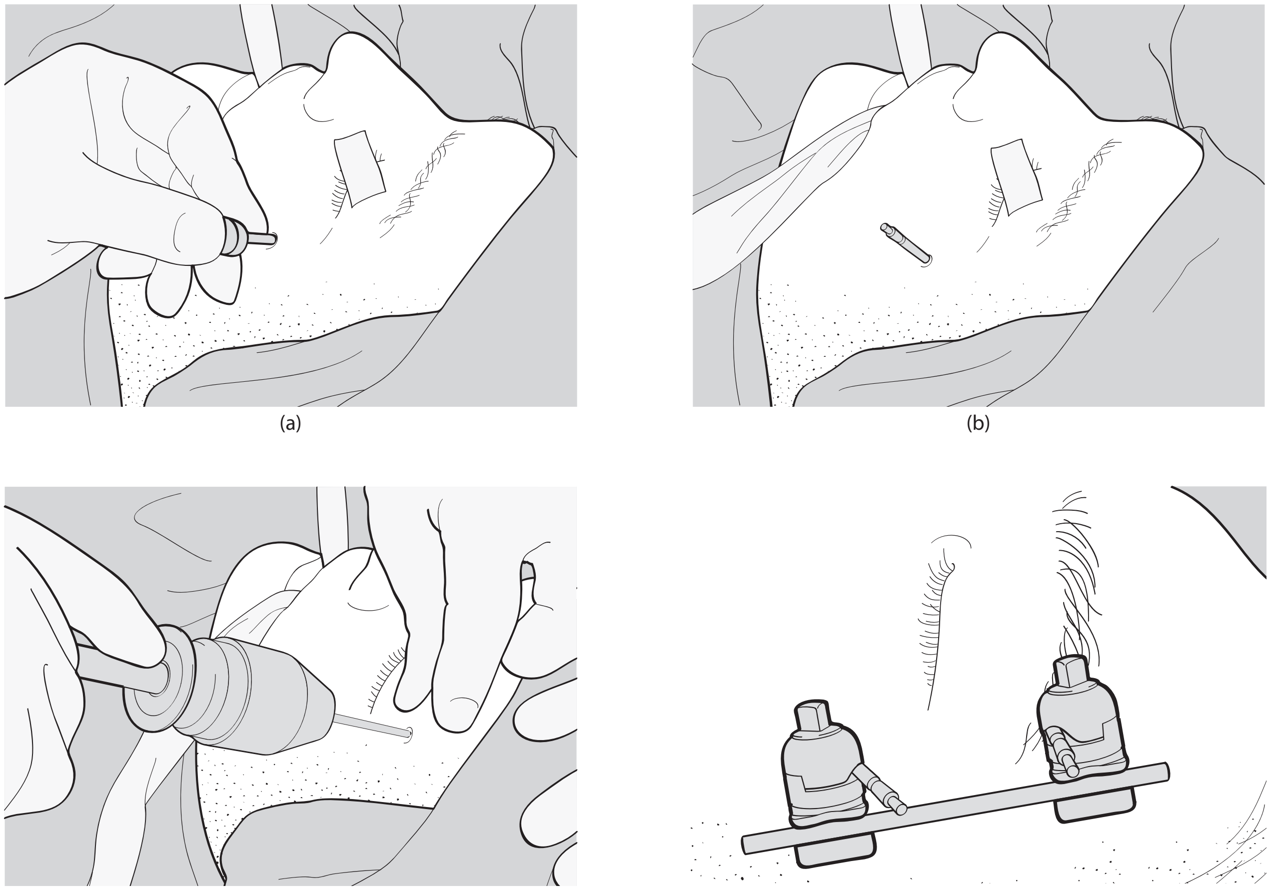


Figure 60.6 An FZ plate, via upper blepharoplasty incision. (a) Site of incision marked in upper eyelid. (b) Following skin incision, dissect down to periosteum. (c) Incise periosteum and elevate to expose fracture. (d) Some fractures are easily elevated and plated. If very displaced, screw plate to lower half of fracture first. (e) Use a small hooked instrument or wire to lift and reduce the fracture by applying force through an unused upper hole (do not damage the plate). Drill and screw the other hole. (f) Place second screw. If correctly reduced, this will accurately restore the vertical height.

ANTIBIOTICS, STEROIDS AND TETANUS PROPHYLAXIS

Protocols may vary between different units. Antibiotics may be given to prevent sinusitis. Penicillin (or a cephalosporin) and metronidazole is one option, but many exist. Some surgeons prescribe steroids (dexamethasone/methylprednisolone) to reduce post-operative orbital swelling.



(a) (b) (c) (d)

Figure 60.7 External fixation (see Chapter 58 for sequence). (a) Stab incision and trochar over cheek. (b) Following drilling, pin screwed into bone. (c) Procedure repeated for frontal pin. (d) Final assembly. Leave some space between joints and skin for hygiene and swelling.

POST-OPERATIVE CARE

The main concerns here are to ensure that the fracture stays in the correct position and serious complications such as loss of sight and severe infections do not develop. As patients wake up, they may be initially agitated and the repaired site must be protected from inadvertent injury. Various ways of achieving this are possible, but having the site clearly marked and an alert recovery/ward nurse go a long way to achieving this. Swelling and bleeding behind the globe can occur, which unrecognized can result in loss of vision. Careful observation of the eye is therefore important, at least until the patient is awake. Various regimes exist. Antibiotics and steroids may be continued for a variable time and patients should be advised not to blow their nose.

RETROBULBAR HAEMORRHAGE/ORBITAL COMPARTMENT SYNDROME

Proptosis following injury or repair needs to be evaluated quickly and carefully. The concern here is loss of sight following retinal/optic ischaemia. For this reason, the eye is put under careful observation, usually until the next day, although they can probably be stopped when the patient is fully awake. Progressive pain, deteriorating vision, proptosis and ophthalmoplegia are the main signs to check. Traditionally, acute proptosis is considered to be a retrobulbar haemorrhage (RBH), although in the author's experience (and as published) RBH is rarely the cause. Once the orbit/zygoma has been reduced, the orbit becomes a closed space and swelling is contained, resulting in an orbital compartment syndrome (OCS). For this reason, steroids are variably prescribed post-operatively. The key to urgency of treatment is the visual acuity, if the vision is normal, decompression is not required. Rarely do such cases need to be returned to theatre, but if they do it should be remembered that an OCS may not release blood, in which case if the proptosis is that severe, decompression will be required. Intravenous acetazolamide, mannitol, steroids and a lateral canthotomy buy time while theatre preparations are being made. If in doubt, globe tension should be measured by a 'tonopen' or other suitable device.

Top tips

- If the eyelids are swollen, gently pressing on them (not the globe) for a few minutes reduces this sufficiently to assess visual acuity.
- Numbness of the cheek and upper lip is an important sign that should generate a high index of suspicion for orbital or cheek bone fracture.
- Remember the nasolacrimal duct during infraorbital/eyelid access.
- Isolated arch or simple fractures which are incomplete at the FZ suture are those most suitable for closed reduction.
- Arch fractures with associated coronoid fractures are at risk of ankylosis.
- Correct alignment of the sphenozygomatic suture (lateral orbital wall) is a good on-table indication that the fracture is correctly reduced.
- A force duction test should be performed at the end of any reduction. As the fractures realign, orbital soft tissues may become trapped.
- Beware of late enophthalmos – follow up patients closely.
- Place sticky tape over the repaired site. Do not draw on the patient – they may try and rub it off.
- Not all vision-threatening proptoses are due to RBH.

SECTION VIII

TEMPOROMANDIBULAR JOINT DISEASES

61

Temporomandibular joint arthroscopy: Diagnostic and operative technique

JOSEPH P MCCAIN and KING KIM

CONTENTS

INTRODUCTION

Arthroscopy of the human temporomandibular joint (TMJ) was first introduced by Ohnishi in 1975.[1] The current diagnostic and operative technique will be presented. Meticulous attention to detail is required to successfully perform the procedure. Any alteration or compromise of the step-by-step surgical sequence will alter the ability to complete the planned procedure and will compromise the outcome. Operations are done in the superior joint space unless disc perforations exist which allows entry into the inferior joint space.

PATHOLOGY

The TMJ is a synovial joint subject to similar pathology as with other synovial joints. A basic difference, however, exists in that fibrocartilage rather than hyaline cartilage lines the articular surface. Fibrocartilage consists mainly of collagen types I and II, and is a mixture of dense fibrous tissue and cartilaginous tissue. Hyaline cartilage is composed primarily of type II collagen and is primarily cartilaginous tissue. Osteoarthritis is the end point of the natural history of degenerative disease. This may develop primarily or as a result of the traumatically dislocated interposing articular disc. Important structural anatomy of the TMJ is shown in Figure 61.1.

The displaced disc causes pain and mechanical locking of the mandible. Synovial adhesions often accompany the herniation of the disc into the anterior recess. Central perforations of the disc occur in primary osteoarthritis. Perforation of the posterior ligament occurs in chronic dislocated discs secondary to micro- or macro-trauma. A conservative surgical cascade is advocated to manage the disease process. Evidence-based research has shown that restoration of normal anatomy or removal of the diseased

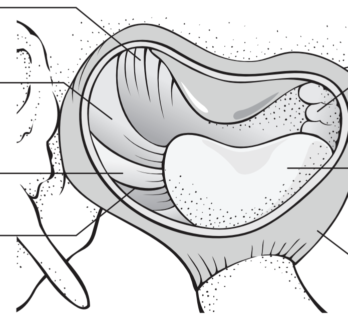


Figure 61.1 Anatomy of the temporomandibular joint (TMJ) as it relates to arthroscopy.

perforated disc is not always needed to obtain a return to relatively pain-free function.

INDICATIONS

Although there are exceptions, patients who undergo initial consultation for TMJ pain, pain with joint noise or restricted mouth opening should undergo conservative non-surgical therapy prior to any type of surgical intervention. This essentially includes teaching the patient about limiting eccentric jaw movements, eliminating any pathologic habits (gum chewing, opening mouth excessively wide etc.), having the patient undergo Boering therapy which is educating the patient about their problem, and instructing them to partake of a softer diet and to habitually perform non-clenching techniques. In addition, these patients should begin a regimen of oral anti-inflammatory medications to decrease any acutely inflamed process, and wear a soft orthotic device to either eliminate a bruxing habit or to soften the load placed on the TMJs during bruxism. The chronic bruxer can also benefit from an oral muscle relaxant to minimize the load as well. The exceptions to this general rule will include, of course, those patients who present for initial consultation who have already undergone the aforementioned conservative therapy with little or no positive results.

After 2–4 months of conservative therapy, the patient is re-evaluated for their condition. Sometimes, the problem(s) will be resolved with these measures and no additional treatment is warranted. However, there are many patients who are refractory to this conservative approach, and who desperately wish for a resolution to their problem. This is where a discussion with the patient about minimally invasive TMJ surgery is indicated.

The patient is made aware that arthroscopic TMJ surgery may not alleviate the patient's symptoms and that open joint surgery is indicated if more conservative treatment modalities fail. Additionally, the patient is informed of the possibility of seventh nerve deficits secondary to extra-oral punctures, malocclusion following surgery, possible scar formation from the punctures, as well as the possibility for pain, bleeding, swelling, and post-operative infection.

The next step is making a decision on the type of arthroscopic procedure that the patient will receive. This obviously must be ascertained based on the diagnosis made. For example, a patient with a clicking joint, intermittent pain and 35 mm maximal incisal opening (MIO), with a Wilkes' stage II may benefit from a lysis of adhesions with lavage of the superior joint space to relieve the symptoms (lysis and lavage procedure). Then again, a patient who is in extreme pain with an anteriorly dislocated disc, which is non-reducing on magnetic resonance imaging (MRI), an MIO of 20 mm, with a preliminary Wilkes' stage IV, may benefit from a surgical arthroscopy procedure consisting of anteriorly releasing the disc with posterior repositioning, and fixating the disc to the condylar head arthroscopically (arthoscopic discopexy procedure) (Table 61.1).

PERI-OPERATIVE CONSIDERATIONS

When the patient is ready for surgery, it is important to wrap the patient's head with a sterile drape prior to entering the operating room to keep hair out of the operative field. When the head is wrapped securely, it allows the procedure to be clean and less cumbersome. In addition, the possibility of infection is minimized.

The procedures for TMJ arthroscopy are best performed under general anaesthesia via nasal intubation. It is crucial that the assistant is able to manipulate the mandible and close the jaw into occlusion without the endotracheal tube

Table 61.1 Clinical and radiologic criteria for Wilkes' staging of temporomandibular joint (TMJ) internal derangement

Stage	Clinical findings	Radiological findings
I	No significant mechanical symptoms, no pain or limitation of motion	Slight forward displacement and good anatomic contour of disc
II	First few episodes of pain, occasional joint tenderness and related temporal headaches, increase in intensity of clicking, joint sounds later in opening movement, beginning transient subluxations or joint locking	Slight forward displacement and beginning anatomic deformity of disc, slight thickening of posterior edge of disc
III	Multiple episodes of pain, joint tenderness, temporal headaches, locking, closed locks, restriction of motion, difficulty (pain) with function	Anterior displacement with significant anatomic deformity/prolapse of disc, moderate to marked thickening of posterior edge of disc, no hard-tissue changes
IV	Characterized by chronicity with variable and episodic pain, headaches, variable restriction of motion and undulating course	Increase in severity over intermediate stage, early to moderate degenerative remodelling hard-tissue changes
V	Crepitus on examination, scraping, grating, grinding symptoms, variable and episodic pain, chronic restriction of motion, difficulty with function	Gross anatomic deformity of disc and hard tissue, essentially degenerative arthritic changes, osteophytic deformity, subcortical cystic formation

getting in the way. If, however, the surgeon and patient elect to do a procedure such as arthroscopic arthrocentesis in an office setting under local anaesthesia and light sedation, the patient must be able to follow commands of moving the jaw open and closed and into lateral excursions during the procedure. A diagram of patient positioning in the operating room setting is shown in Figure 61.2, and arthroscopic set up is shown in Figure 61.3.

Peri-operative medication considerations are crucial to attaining optimal results with TMJ arthroscopy. The use of prophylactic antibiotics to prevent post-operative infection is controversial. The orthopaedic literature in regards to arthroscopy is scant with good prospective studies, since the incidence for infection following arthroscopic procedures is so low. The American Academy of Orthopaedic Surgeons has not produced an advisory statement regarding the issue. However, literature does exist essentially stating that antibiotic prophylaxis for arthroscopic procedures is not indicated for healthy patients. It is the opinion of the authors that antibiotic usage is indicated for those prone to infection. These include patients with diabetes, compromised immunity, or skin disorders. When antibiotics are indicated, 1 g of cefazolin given intravenously 1 hour prior to the procedure provides good coverage to prophylactically manage these patients.

Intravenous administration of corticosteroids prior to the procedure is an important consideration to prevent post-operative oedema. In the immediate post-operative period following TMJ arthroscopic procedures it is crucial to initiate mandibular motion and mouth opening exercises to prevent arthrofibrosis, haemarthrosis, and train the muscles of mastication to stretch. Oedema interferes with this ability to achieve the goal of improved mandibular functioning. Because of this, it is advisable to administer post-operative dosing regimens of corticosteroids in a tapered fashion.

As discussed earlier, the importance of instructing the patient to move the mandible post-operatively cannot be overemphasized. Patients are given these directions for jaw hinge exercises the day of or the day following surgery. These exercises are classified as stages I and II. Stage I exercises consist of taking the tongue, rolling it as far back on the palate

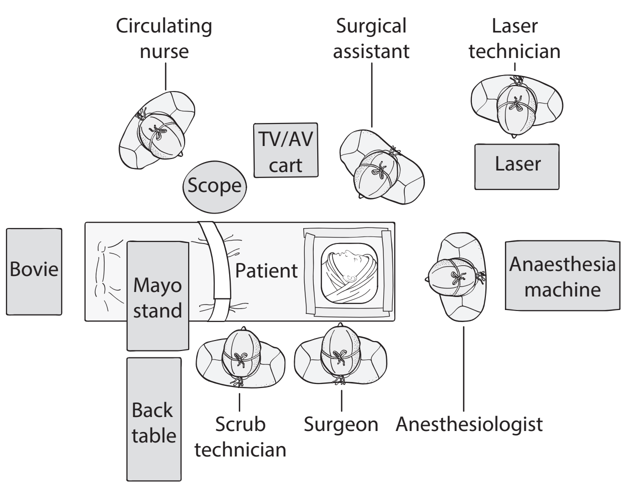


Figure 61.2 Patient positioning in the operating room.

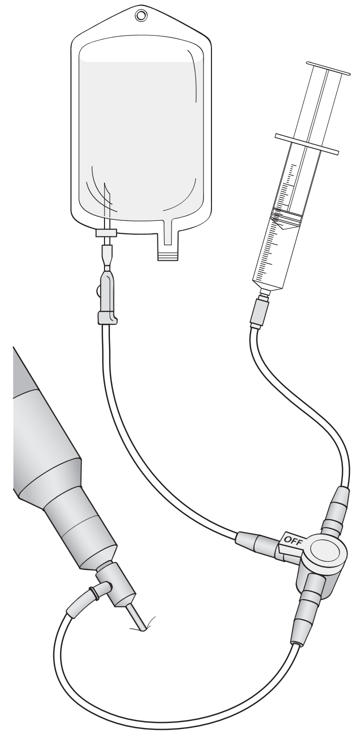


Figure 61.3 TMJ arthroscopic set up.

as possible, and opening as wide as possible without disengaging the tongue. The second of these exercises is to move the jaw in lateral and protrusive excursions as far as possible. Both sets of exercises are to be performed for 20 repetitions, 4 times per day. Stage II exercises involve the pry bar, painting of teeth and rubber tubing. The pry bar is placing the thumb on the upper incisors, the middle finger on the lower incisors, and prying to maximum incisal opening. The painting of teeth involves taking the tip of the tongue and starting at the buccal surface of the most posterior molar, painting all of the teeth from right to left and back again. Lastly, a piece of rubber tubing is placed between the canines on one side and moving into lateral excursions whilst lightly biting on the rubber tubing. Each of these exercises is performed for 20 repetitions, 4 times per day.

Most patients are instructed to follow stage II exercise, but stage I exercises are indicated for patients under certain circumstances. For example, patients who undergo semi-rigid discopexy repair with the suture technique to treat anterior disc dislocation could very easily relapse back into the anterior disc position if translation is initiated too early. The same is true for those patients who receive posterior retrodiscal scarification procedures to treat slightly dislocated discs. Also, in those patients treated for condylar subluxation who undergo posterior retrodiscal release need to undergo opening exercises in reverse after surgery. This is to say that they need to prevent translating their condyles to allow the disc to settle into correct position. In all three of these instances, the patient is only gradually worked into full function due to the instability of the disc position, and potential for relapse of an anteriorly dislocated disc.

SURGICAL CASCADE

Regardless of the pathology the recommended surgical cascade is as follows:

1. Arthroscopic arthrocentesis
2. Lysis and lavage with debridement
3. Discopexy
4. Contracture for mandibular dislocation

A diagrammatic view of the relevant TMJ anatomy as it relates to puncture is shown in Figures 61.4 and 61.5.

Arthroscopic arthrocentesis

This procedure essentially involves the single puncture technique. The single puncture technique is shown in Figure 61.6.

The thumb is used to palpate the maximum concavity of the glenoid fossa at the junction between the periosteum and synovial capsule. The bony landmark is the maximum concavity of the inferior aspect of the zygomatic and temporal bones. To facilitate precision of the technique, this puncture should be done with a sharp trocar. Throughout the puncture into the superior joint space, the trocar and cannula are advanced deeper into tissues utilizing a twisting and rotational motion to prevent injury to the facial nerve and to provide better control of the sharp instrument. After puncturing skin, the trocar is used to scrape off soft-tissue attachments subperiosteally at the maximum concavity of the glenoid fossa. The trocar and cannula are then redirected medially to enter the superior joint space. A depth of 20–25 mm indicates a safe puncture. Any more and the risk of perforating through the medial synovial drape increases. It is important that the scope enters the joint as supero-lateral as possible for best visualization. Once inside the joint, the lavage of the joint ensues, and irrigating needle is placed for outflow. The 22-gauge irrigating needle can be inserted 5 mm anterior and 5 mm inferior to the first puncture. It is important to insufflate with 2–3 cc of fluid prior to placing the irrigating needle to prevent collapse of the joint space (Figures 61.7 through 61.9).

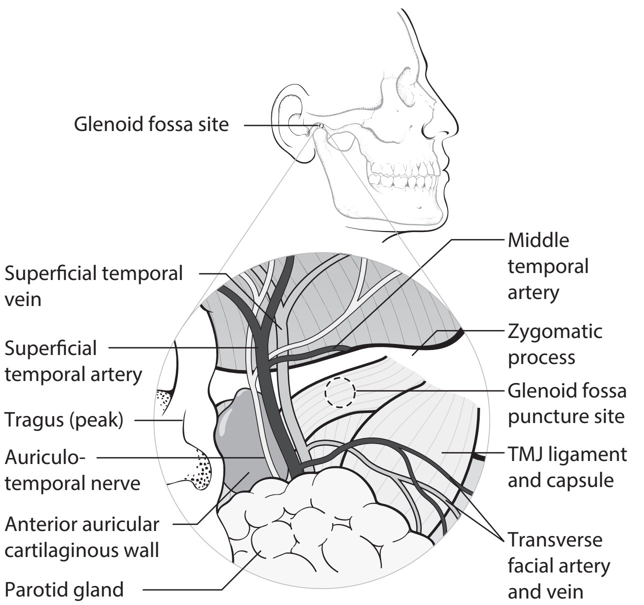


Figure 61.4 Anatomy relevant to single puncture technique.

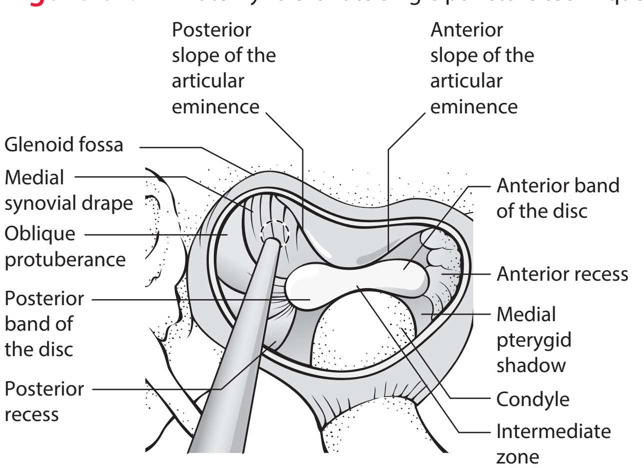


Figure 61.5 Anatomy and puncture location.

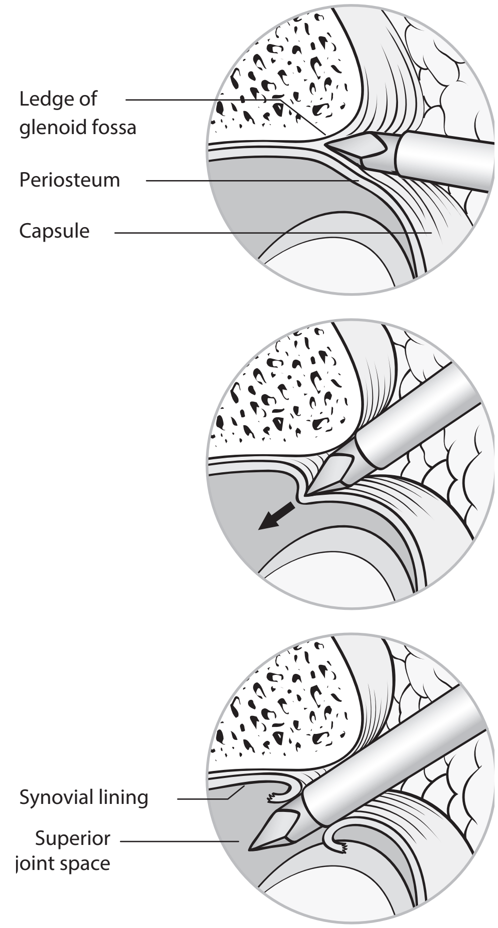


Figure 61.6 Single puncture technique.

Lysis and lavage with debridement

This procedure involves the double puncture technique. The fossa portal is created as described by the single

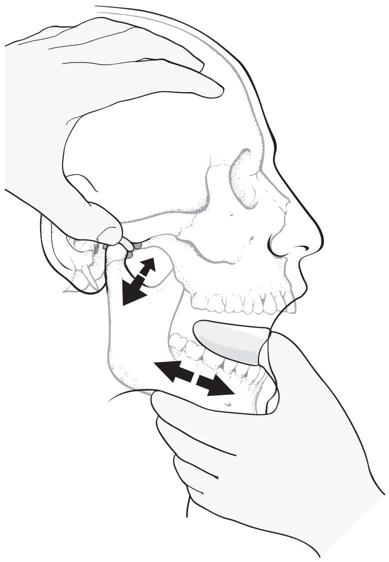


Figure 61.7 Operator and assistant collaborating to locate correct puncture location.

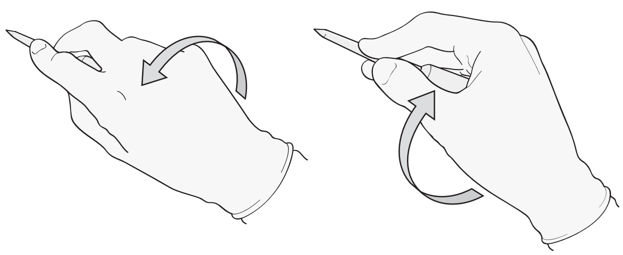


Figure 61.8 Rotational hand movement for puncturing superior joint space.

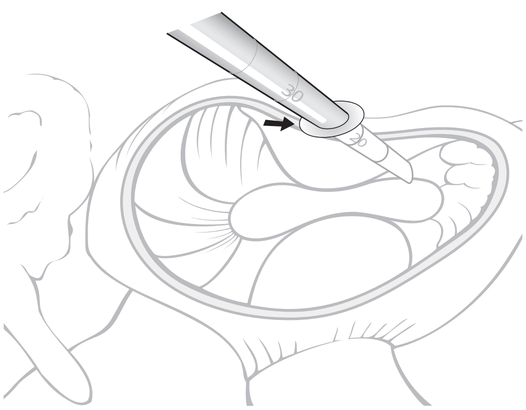


Figure 61.9 Diagrammatic representation of depth of puncture.

puncture technique. Once the arthrosopic cannula with arthroscope is inserted, the articular eminence portal is then created by triangulation. To perform this technique, the most superior, anterior and lateral aspects of the articular eminence are targeted. The lavage needle is removed, and a 2.0 trocar and cannula is introduced into the superior joint space. The second cannula inserted is known as the working cannula. The working cannula is used to accommodate instrumentation such as holmium lasers, shavers, graspers, straight probes, hook probes, as well as certain medicaments if they are needed. The size of the working cannula can be increased as needed (Figures 61.10 through 61.14).

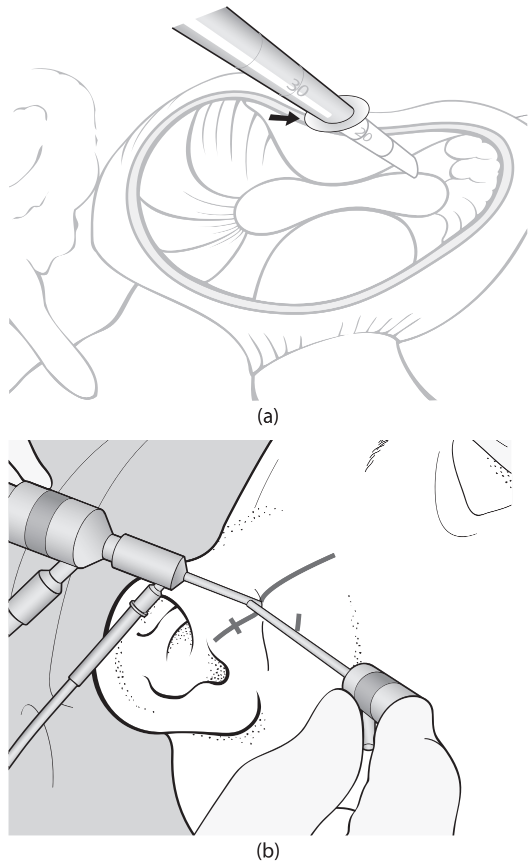


Figure 61.10 (a) Measuring second puncture point. (b) Measuring second puncture point.

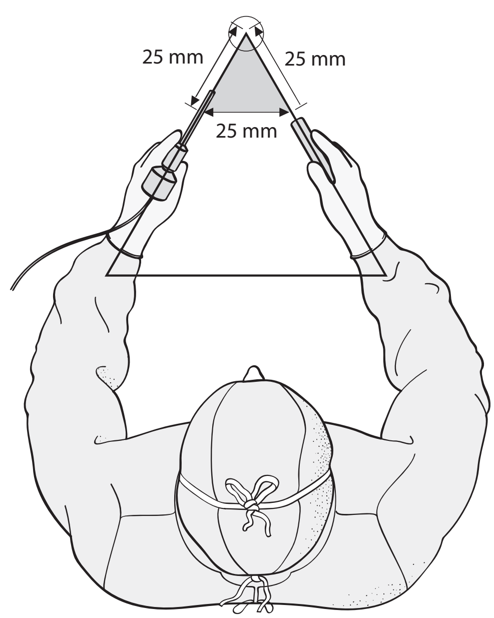


Figure 61.11 Triangulation concept.

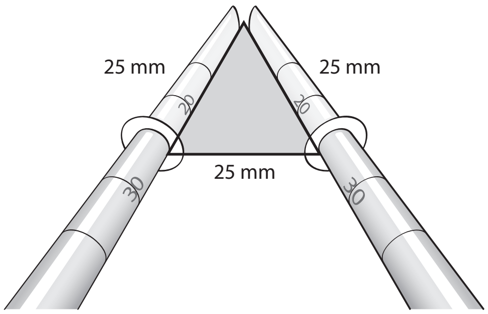


Figure 61.12 Triangulation concept magnified.

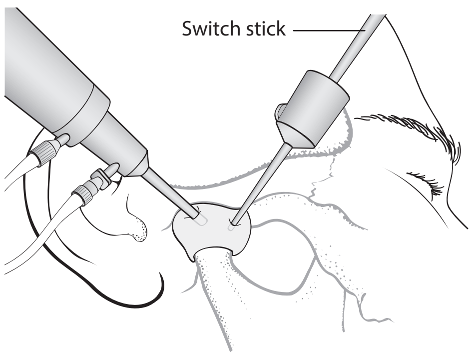


Figure 61.13 Triangulation on patient.

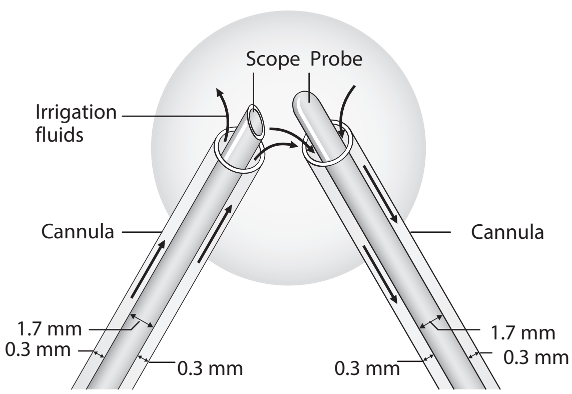


Figure 61.14 Instrumentation through both cannulas.

Discopexy

This procedure, which is the most complex, involves three to four punctures into the superior joint space. For rigid discopexy (fixating the reduced disc with resorbable screws or nails), three punctures are utilized. In addition to the arthroscopic cannula and the working cannula as previously described, the third puncture involves creation of the fixation portal for insertion of the fixation cannula. For semi-rigid discopexy (fixating the reduced disc with sutures), four punctures are utilized. The arthroscopic cannula, working cannula and fixation portal which accommodates two needles for sutures: one anterior and one posterior.

For either rigid or semi-rigid discopexy, an anterior release must be performed prior to fixation. The anterior release is best performed through the working cannula with a holmium laser. The disc-synovial crease is delineated and scored with a hook probe, and the laser is used to cut along scored area, making sure to detach the superior head of the lateral pterygoid from the disc tissues. After adequate release is performed, the straight probe is utilized to reduce the disc posteriorly, whilst the mandible is in the forward position. The retrodiscal tissues, at this time, can be ablated with bipolar cautery or a holmium laser as a means to scar the tissues and keep the disc reduced.

For the rigid discopexy procedure, the fixation portal is created whilst a straight probe in the working cannula reduces the disc posteriorly. The trocar and cannula targets the posterior lateral disc attachment. A 22-gauge needle is used to sound the area predicted for puncture. Whilst the mandible is in the forward position, the fixation portal is created 20 mm inferior to the fossa portal.

Rigid fixation of the disc to the condylar head can now be performed through the fixation cannula which is approximately 3.0–3.5 mm in diameter. Fixation is done with either resorbable screws or nails, and can be done with 1, 2 or 3 depending on the amount of access that is available. Post-operative rehabilitation consists of immediate functioning with stage II exercises, as disc position is secure. The correct position of the three cannulas is shown in Figure 61.15, whilst pictures of the technique is shown in Figures 61.16 through 61.18.

For semi-rigid fixation, or suture discopexy, the fixation portal is created the same way as in the rigid fixation technique. The anterior release is shown sequentially in Figure 61.19a through c. Through the fixation cannula, a vector is aimed at the postero-lateral attachment. A straight meniscus mender is then punctured under the reduction cannula to the condylar head then superiorly through the posterior lateral portion of the disc. A second meniscus mender is then punctured through skin and is used to catch the suture (Figure 61.20). A 0-PDS suture is then passed anteriorly and a snare is used to catch it posteriorly (Figure 61.21). The location of the suture

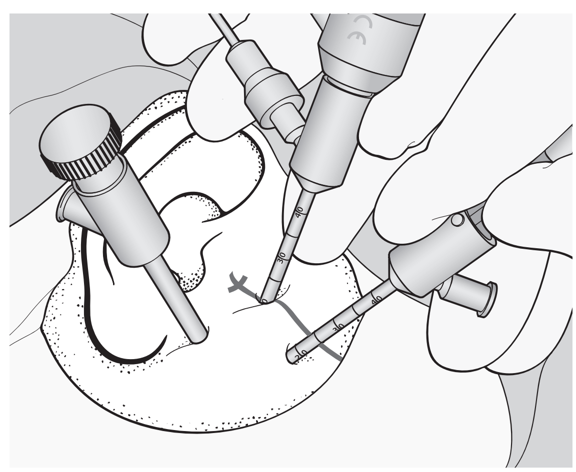


Figure 61.15 View of arthroscopic, working, and fixation cannulas.

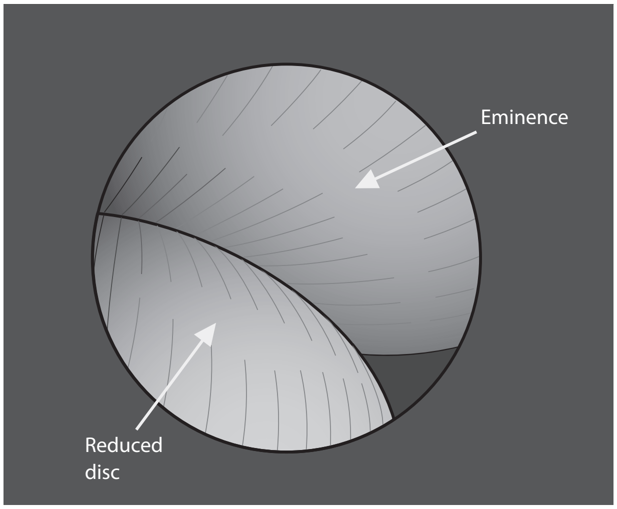


Figure 61.16 Arthroscopic picture of disc in reduction.

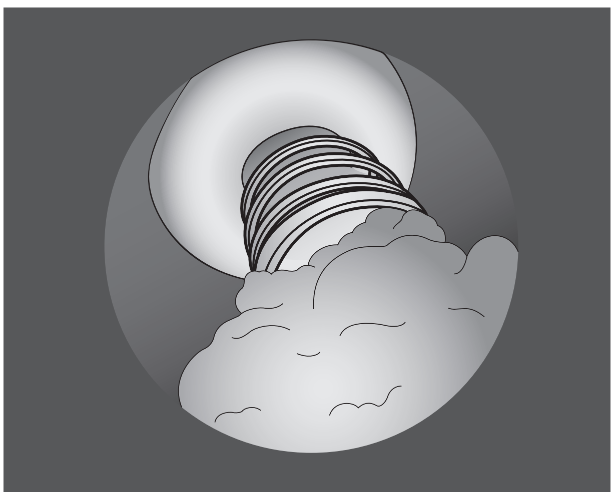


Figure 61.17 Arthroscopic picture of rigid fixation technique.

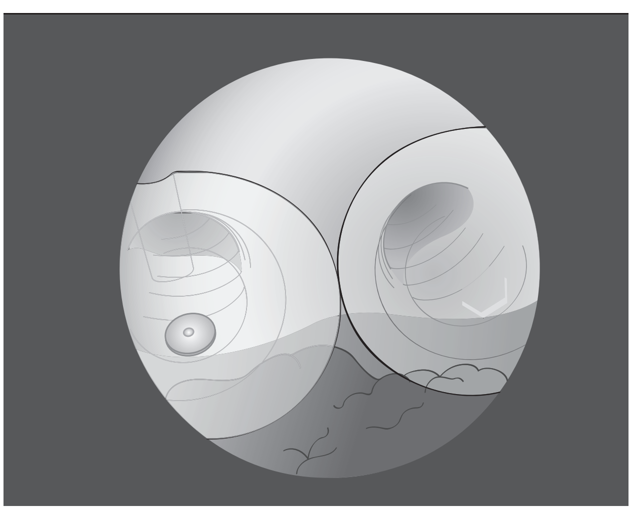


Figure 61.18 Arthroscopic picture of resorbable screw fixation in place.

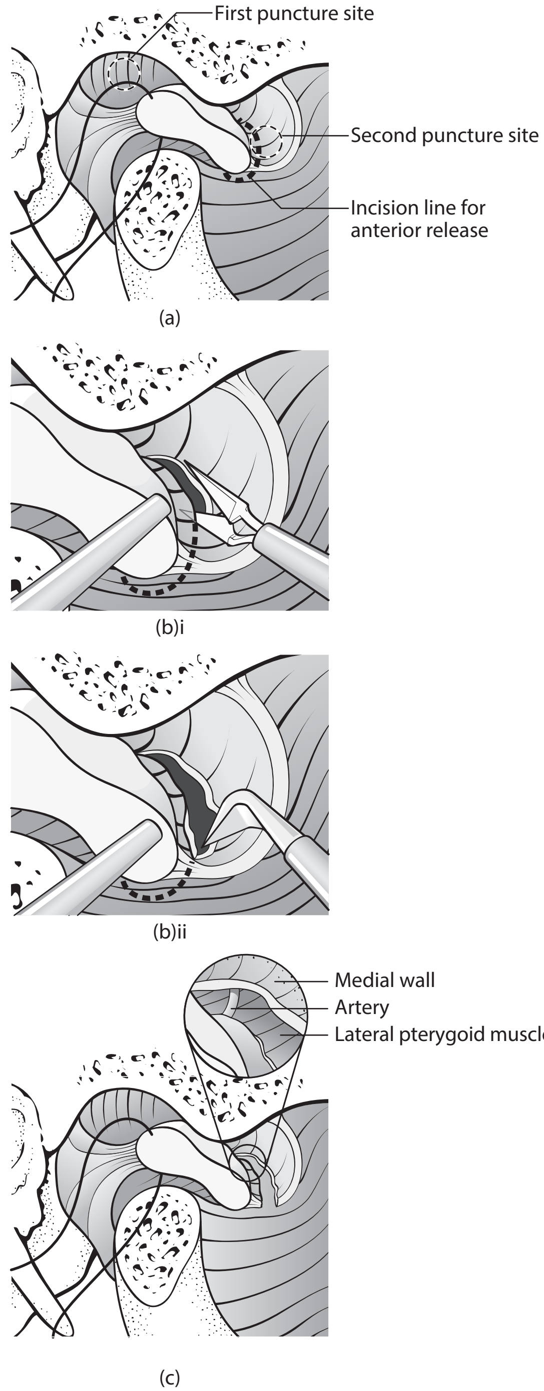


Figure 61.19 (a) Outlined location of anterior release. (b) Making anterior release. (c) Anterior release completed with associate anatomical structures.

when it is pulled through skin is parallel and inferior to the apex of the tragal cartilage. A small skin incision is made after the suture is passed through, and a surgeon's knot is tied to capsule and disc (Figures 61.22 through 61.25). Post-operative rehabilitation for these patients is slow and requires only limited amount of jaw mobility initially, gradually increasing to stage II exercises and beyond.

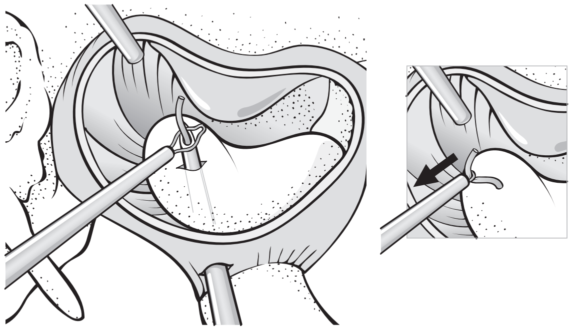


Figure 61.20 Suture discopexy. Meniscus mender being used to catch the suture.

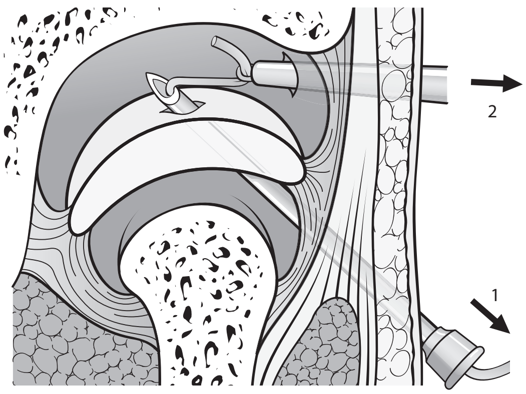


Figure 61.21 Suture discopexy. A snare is used to catch the PDS suture.

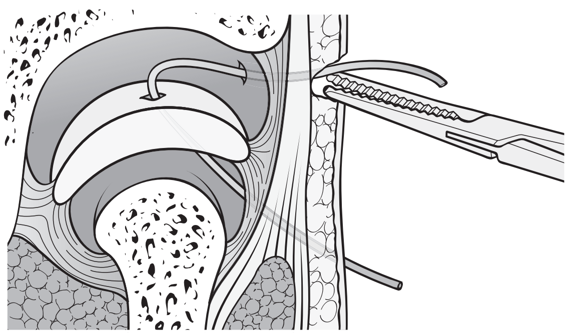


Figure 61.22 Suture discopexy. The two ends of the discopexy suture emerge through the overlying skin.

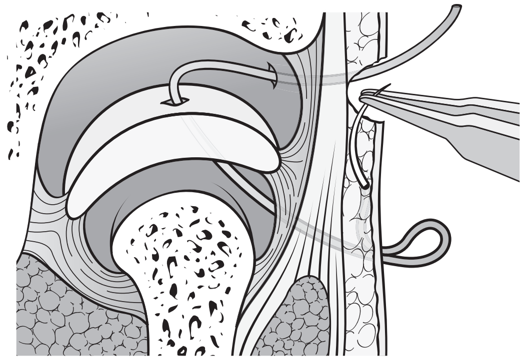


Figure 61.23 Suture discopexy. The sutures are then passed deep to the skin using the needles prior to tying the surgeon's knot.

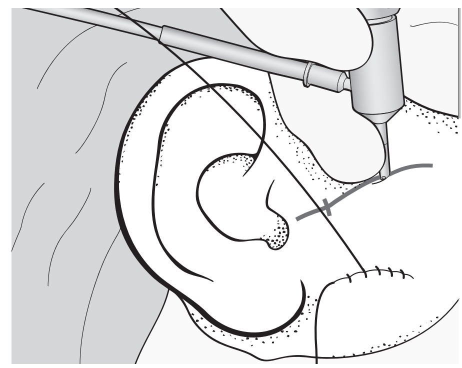


Figure 61.24 Suture discopexy.

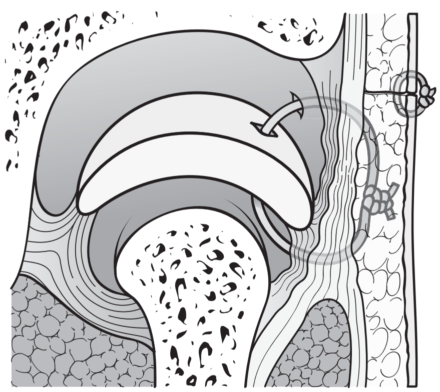


Figure 61.25 Suture discopexy. The disc is anchored to the joint capsule and the surgeon's knot is buried under the skin.

COMPLICATIONS

Overall, TMJ arthroscopy is a safe procedure. It is minimally invasive, and can be performed in an outpatient setting. Complications do, however, exist. These include facial nerve trauma, arthrofibrosis, infection, perforation into the ear canal or tympanic membrane and subdural or epidural haematoma from perforation into the middle cranial fossa. Management of these complications is outside the scope of this chapter, however, with good surgical technique and attention to detail, as well as procedure selective post-operative rehabilitation, these complications can be reduced to almost none.

Top tips

- Patient positioning is paramount. If you start behind, you will become flustered for the entire procedure. Make sure the patient's head is turned and flat on the table, which will facilitate an easier puncture. Each step of arthroscopy is dependent on the successful completion of the previous one. It is impossible to perform advanced procedures if this principle is not strictly adhered to.
- Always use landmarks. It is easy to become lost during a puncture. If you feel like no progress is being made, then back away, orient yourself with the known landmarks (zygomatic process of temporal bone, glenoid fossa and condylar head) and use these to make an accurate puncture. Use the vectoring measuring system for all multiple punctures.
- Make sure to gather all information. Once inside the joint, a thorough diagnostic arthroscopy is crucial to treating the condition. Make note of everything that comes into view (perforated disc, hyperaemic retrodiscal tissues, amount of dislocation etc.) and use this knowledge to come up with the best possible treatment.
- Do not rush. The temptation to rush through a part or all of this procedure will most likely lead to unfavourable results. Make sure to take extra time to explore the entire posterior pouch, the anterior recess, and if the second or third punctures are not entering the joint space in a timely fashion, be patient and do it right. It is not the job of the practitioner to make the patient worse.
- Be aware of all danger zones inside the joint space. It is important to keep the depth of fossa puncture to 25 mm or less and the vector of puncture anterior. Failure to do so may result in perforation of the tympanic membrane. Never move the operative cannula instrumentation posteriorly unless under direct arthroscopic control. Blind manoeuvres risk perforation of the medial synovial drape and the risk of injury to the tympanic membrane and or perforation through the glenoid fossa into the middle cranial fossa. Always arthroscopically visualize the insertion and movement of the operative cannula in the anterior recess. Blind manoeuvres may lead to a laceration of the middle meningeal artery and or the lingual nerve.
- Make sure to prevent extravasation. Avoid careless multiple punctures. Always maintain a patent irrigation system. Lack of a good lavage needle to drain the insufflated joint space will result in extravasation of irrigating fluid, which can be seen clinically as a swelling of the affected side of the face. Extravasation into extra capsular tissues can lead to trismus, pain, malocclusion, facial nerve paresis, and increased recovery time. In addition, if an anterior release of the disc is performed, the fluid could extravasate into the pterygoid space and further into the lateral pharyngeal space, leading to a very difficult airway situation.

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62

Surgery to the temporomandibular joint

GEORGE DIMITROULIS

CONTENTS

INTRODUCTION

Arthrotomy refers to the direct surgical exposure of a joint. A temporomandibular joint (TMJ) arthrotomy is technically one of the more difficult surgical dissections in the maxillofacial region. Whilst the close proximity of the facial nerve is the main reason for the difficult surgical access, other important anatomical structures such as the complex distribution of the superficial temporal vessels also add to the complexity of the dissection. With the middle cranial fossa above, the internal maxillary artery medial to the TMJ, and the middle ear behind the TMJ, there is little room for surgical error as these anatomical structures are only a few millimetres away from the joint itself.

INDICATIONS FOR TMJ ARTHROTOMY

Surgery to the TMJ is undertaken for a wide range of joint disorders. Indications for surgical intervention are divided into absolute and relative.

Absolute indications: TMJ surgery has a definite and undisputed role in the management of uncommon joint disorders such as the following:

1. Dislocation – i.e. recurrent or chronic
2. Ankylosis – e.g. fibro-osseous joint fusion
3. Neoplasia – e.g. osteochondroma of the condyle
4. Developmental disorders – e.g. condylar hyperplasia

Relative indications: The role of TMJ surgery in the management of common disorders such as traumatic injuries, internal derangement and osteoarthrosis is less clear and often ill-defined. The indications may be further divided into the following:

1. *General indications*
   a. Where the joint disorder remains refractory to non-surgical therapy involving occlusal splints, medication and physiotherapy
   b. Where the TMJ is the source of the pain and dysfunction hence
      i. Pain localized to the TMJ
      ii. Pain on functional loading of the TMJ
      iii. Pain on movement of the TMJ
      iv. Mechanical interferences within the TMJ

Note: The more localized the symptoms are to the TMJ, the more likely surgery will have a favourable outcome.

2. *Specific indications*: Confirmation of significant joint disease on computed tomography (CT) scan or magnetic resonance imaging (MRI) associated with symptoms of intolerable joint pain and joint dysfunction.

PRE-OPERATIVE PREPARATION

Anaesthesia

TMJ arthrotomy is performed under general anaesthesia using a naso-endotracheal tube to permit manipulation of the mandible that will help identify the position of the mandibular condyle during surgical approaches to the joint.

Position of patient

The patient is positioned in the reverse Trendellenberg slant with the level of the head slightly above the the rest of the body to minimize bleeding. The head is turned away on a 60 degree angle.

Preparation of surgical site

Hair is shaved in front of the ear to the level of the superior tip of the pinna. Three-inch (9–10 cm) wide waterproof tape ('sleek tape') is placed horizontally above the ear and another length of tape is placed vertically behind the ear to cover the hair (Figure 62.1). A marking pen is used to outline the proposed incision line. The surgical site, including the adjacent ear and ear canal, is liberally prepped with antiseptic solution. A sterile ear pledget with vaseline is inserted to protect the ear canal. A turban head drape is wrapped around the head which covers the anaesthetic tube exiting the nose (Figure 62.2). Marcaine (0.5%) with 1:200,000 is infiltrated into the subcutaneous tissues along the incision line and into the joint proper.

OPERATION

Whilst there have been numerous surgical approaches to the TMJ described in the literature, the author uses either a double curved pre-auricular (Figure 62.3) or more commonly an endaural incision (Figure 62.4) with a small temporal extension as his surgical approach. It allows direct surgical access to the joint and provides excellent access for most TMJ surgical procedures including total joint replacements.

Incision

A 5–6-cm curvilinear pre-auricular incision, peaked posteriorly at the level of the tragus (Figure 62.3), is made through skin and subcutaneous tissues. The pre-auricular incision runs around the anterior insertion of the pinna, extending down to the lower border of the insertion of the ear lobe to pre-auricular skin. Alternatively, the inferior incision is made over the crest of the tragus down to cartilage (Figure 62.4), taking care not to cut into the tragal cartilage. Superiorly, a small temporal extension of the incision is made in a forward arc about 45° relative to the zygomatic arch down to subcutaneous fat.

Figure 62.1 Sleek tape used to keep hair away from surgical site.

Skin flap development

Beginning superiorly, the temporal part of the incision is carefully dissected deep towards temporalis fascia with fine curved dissection scissors such as Iris or Tenotomy scissors. Any superficial temporal vessels encountered are either surgically cut and tied or carefully retracted into the anterior flap that is extended anteriorly by blunt dissection with a periosteal elevator.

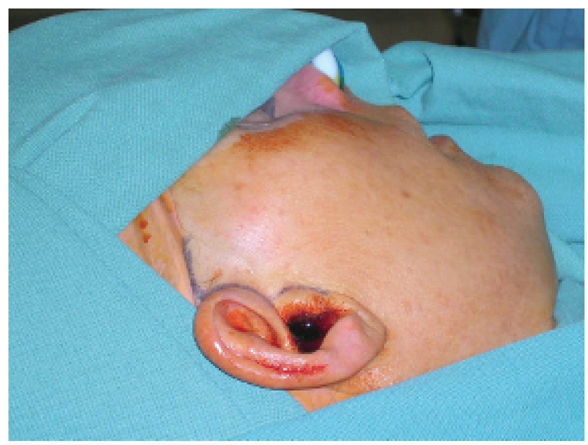


Figure 62.2 Draping of surgical site.

Figure 62.3 Preauricular incision with temporal extension.

Figure 62.4 Preauricular incision.

Inferiorly, the flap is developed with fine curved scissors in a relatively avascular plane parallel to the base of the external auditory (tragal) cartilage (Figure 62.5) which runs anteromedially or along the plane of the tragal cartilage if the endaural approach is used (Figure 62.6).

Temporalis fascia

Once the pre-auricular temporal flap is sufficiently developed to expose the underlying temporalis fascia, the assistant manipulates the mandible whilst the surgeon uses his index finger to feel for the movement of the condyle under the temporalis fascia. Once the position of the condylar head is established, a 2-cm horizontal incision is made through the temporal fascia down to the bone along the root of the zygomatic arch (Figure 62.7). Brisk venous bleeding from deep temporal tissues can be cauterized. Beginning posteriorly, a 45° incision is made inferiorly and the triangular flap created (Figure 62.8) is sharply dissected to lift the temporalis fascia off the lateral TMJ ligament.

Using a sharp periosteal elevator, a flap is developed forwards by blunt dissection exposing the root of the zygomatic arch. Once again, the surgical assistant should manipulate the mandible so the surgeon can palpate for and identify the position of the moving condyle.

Exposing the lateral joint capsule

A sturdy periosteal elevator is used to expose the root of the zygomatic arch as far forwards as the articular eminence. From the pocket created over the root of the zygomatic arch, the lateral ligament (Figures 62.9 and 62.10) is identified inferiorly by sharp and blunt dissection. The lateral ligament is then progressively raised forwards by

Figure 62.5 Raising full thickness skin flap to expose temporalis fascia.

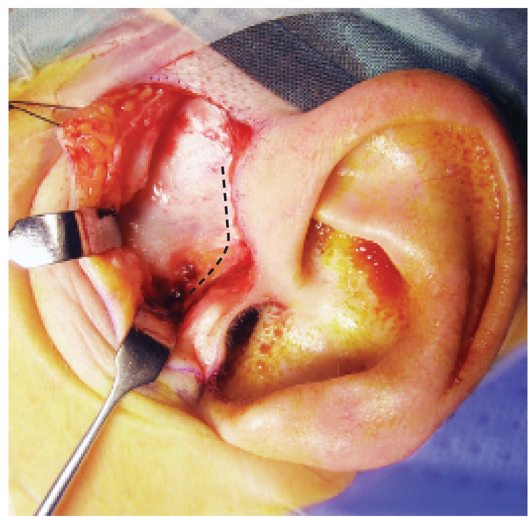


Figure 62.6 Curvilinear vertical incision of temporalis fascia.

blunt dissection over the capsule and lateral margin of the glenoid fossa. This layer is relatively avascular, except inferiorly where branches of the superficial temporal vessels will be encountered and may be cauterized. Access may be extended anteriorly and inferiorly depending on the degree of joint exposure required. At this point, more Marcaine 0.5% with 1:200,000 adrenaline is injected through the capsule.

Entry through the joint capsule

With the condyle distracted inferiorly by the surgical assistant, pointed scissors are used to bluntly enter the superior

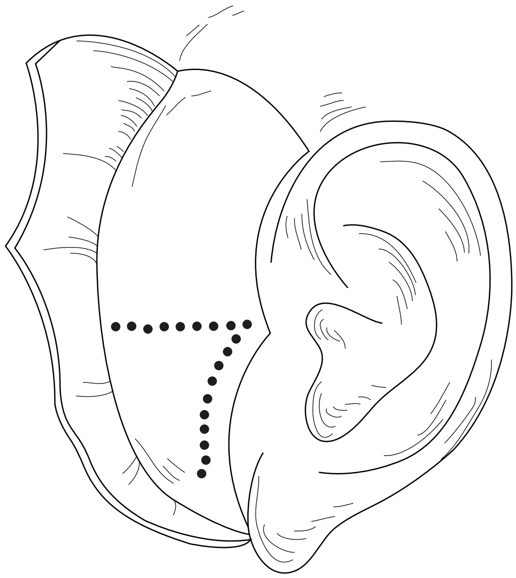


Figure 62.7 Incision of temporalis fascia.

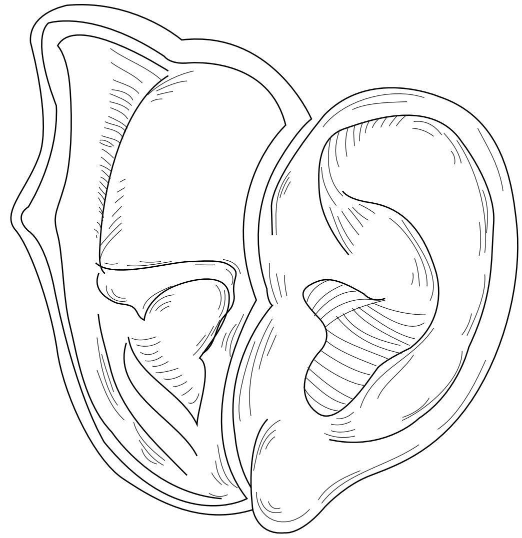


Figure 62.9 Exposed lateral joint capsule.

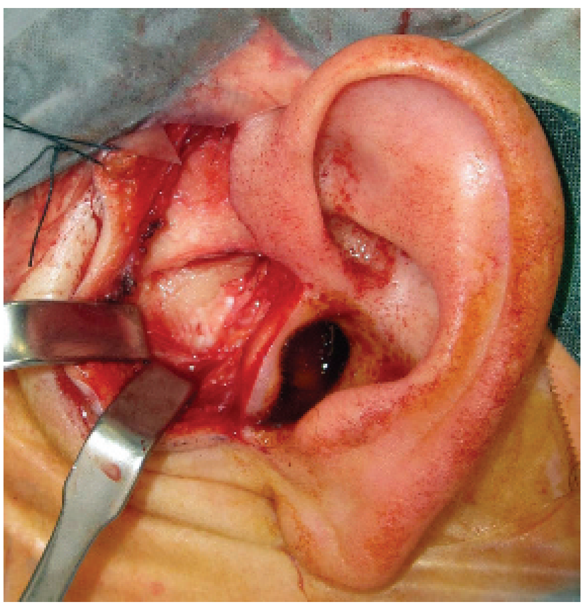


Figure 62.8 Exposure of lateral capsule.

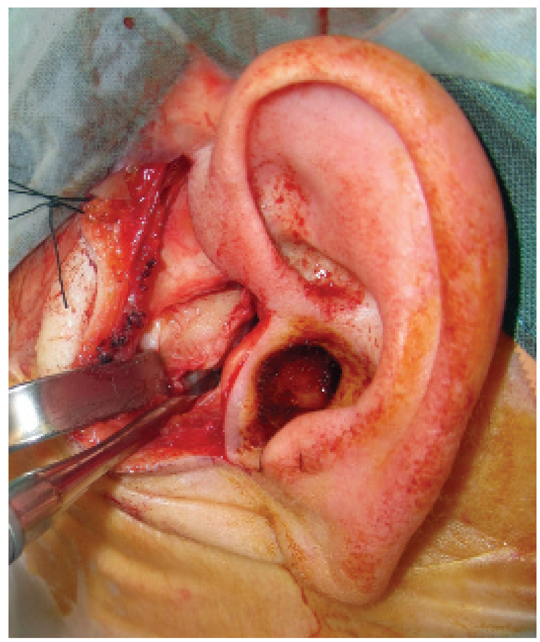


Figure 62.10 Exposed lateral joint capsule.

joint space and opened to reveal the superior surface of the articular disc.

1. *Exposure of superior joint space*: With a small blade, the opening is extended anteriorly and posteriorly by cutting along the lateral aspect of the eminence and fossa (Figure 62.11). The capsule is reflected laterally to reveal the superior joint space (Figures 62.12 through 62.14). A broad periosteal elevator such as a Seldin is then inserted into the superior joint space to help further distract the joint and expose the superior joint space as well as the glenoid fossa and eminence.
2. *Exposure of the articular eminence*: Using a periosteal elevator, the periosteum covering the lateral aspect of the articular eminence is stripped off with forward blunt dissection along the root of the zygomatic arch. Once the anterior and posterior slopes are fully exposed, a small sharp periosteal elevator is directed medially below the greatest convexity of the articular eminence. The medial dissection through the capsule will expose the inferior aspect of the articular eminence which makes up the anterior boundary of the glenoid fossa (Figure 62.15).

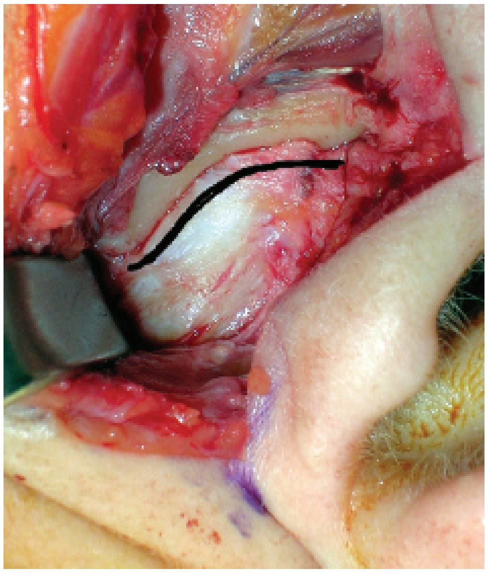


Figure 62.11 Incision into superior joint space.

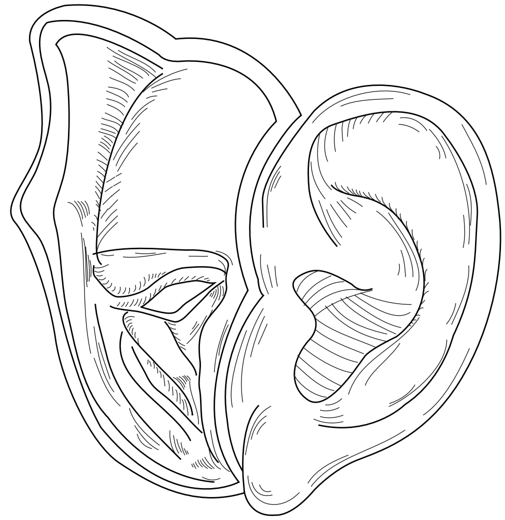


Figure 62.13 Diagram showing exposure of articular disc.

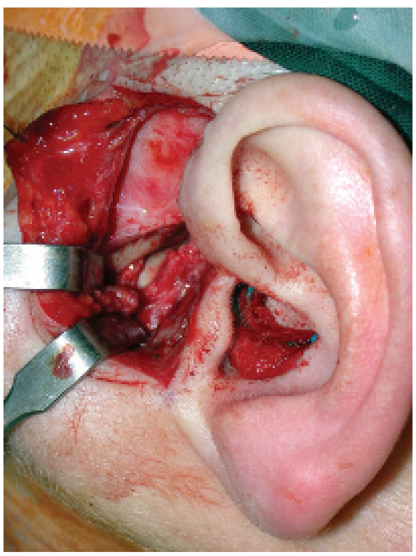


Figure 62.12 Exposure of superior joint space.

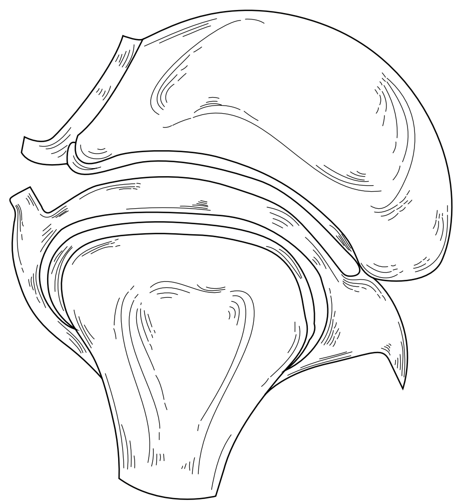


Figure 62.14 Coronal view of surgical approach to superior joint space.

3. *Exposure of inferior joint space*: An incision is made along the lateral attachment of the disc to the condyle within the inferior recess of the capsule (Figures.62.16 through 62.18). Brisk haemorrhage may occur if the posterior attachment of the disc is cut. A fine periosteal elevator is inserted into the inferior joint space to separate the disc from the condylar head and retract the disc superiorly to expose the articular surface of the condyle.
4. *Exposure of the condylar head*: To further expose the condylar head, a vertical relieving incision is made downwards behind the condyle.

Special right angle condylar retractors may then be inserted behind and in front of the condyle to fully expose and stabilize the condyle (Figures 62.19 and 62.20). Anteriorly, the condylar retractor may be inserted below the attachment of the lateral pterygoid muscle to the fovea of the condyle.

SURGICAL PROCEDURES

Articular disc

The articular disc plays a pivotal role in the complex mechanics of joint function. Any change in its physical structure, integrity or position may result in pain and joint dysfunction referred to as internal derangement.

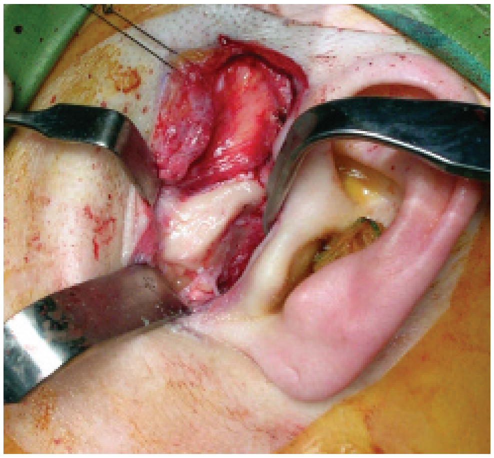


Figure 62.15 Surgical exposure of articular eminence.

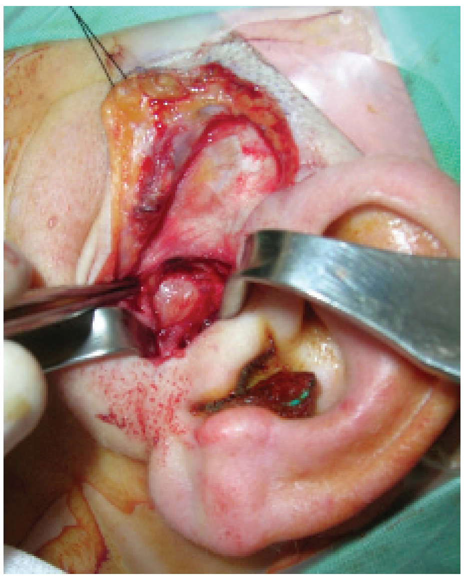


Figure 62.16 Exposure of condylar head.

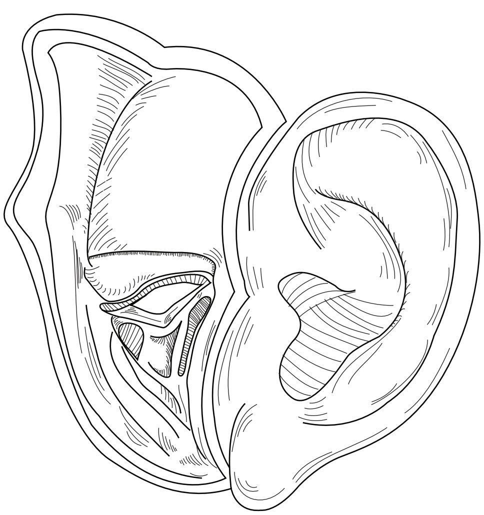


Figure 62.17 Diagram of exposed articular cartilage covering condylar head.

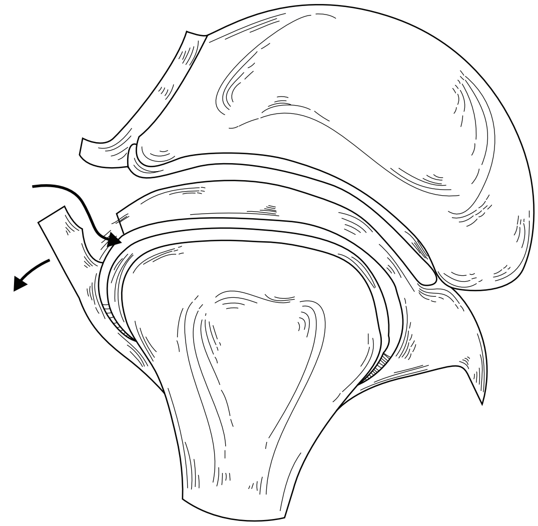


Figure 62.18 Coronal view of surgical approach to inferior joint space.

Figure 62.19 Dotted line showing osteotomy of condylar neck.

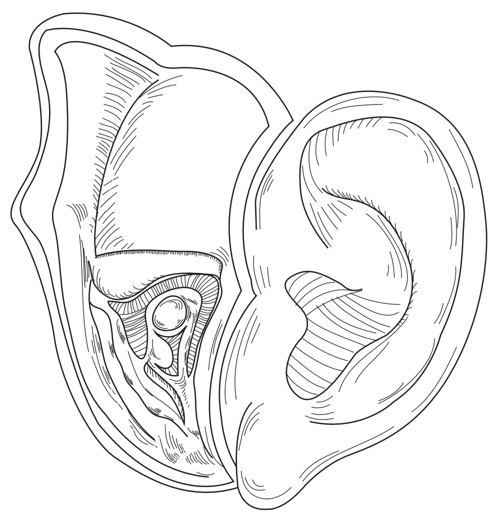


Figure 62.20 Exposure of condylar neck.

The two most common surgical procedures performed on the articular disc are disc repositioning and discectomy.

1. *Disc repositioning*: Upon exposing the superior joint space (Figure 62.14), a blunt instrument such as a Howarth periosteal elevator or Seldin is inserted to help free up the disc anteriorly and medially. The assistant then manipulates the mandible to determine the functional position and integrity of the disc (Figure 62.21). At this point, Marcaine (0.5%) with 1:200,000 adrenaline is injected into the posterior disc attachment and bilaminar tissues before the disc is freed up posteriorly and the vascular retrodiscal tissues are exposed. With minor anteromedial displacements, sufficient redundant tissue within the bilaminar zone can be surgically removed and the disc repositioned posteriorly and laterally. Multiple 4-0 interrupted (non-resorbing) mersilene sutures are placed to anchor the disc to the bilaminar tissues. In situations where the disc is severely displaced, the inferior joint capsule is also exposed (Figure 62.18). A blunt instrument is inserted into the inferior joint space to release the disc from the condylar head and mobilize it further. Redundant tissue lateral and posterior to the posterior band of the meniscus is excised using fine scissors, leaving a rim of vascularized tissue 2 mm from the avascular posterior band of the meniscus.

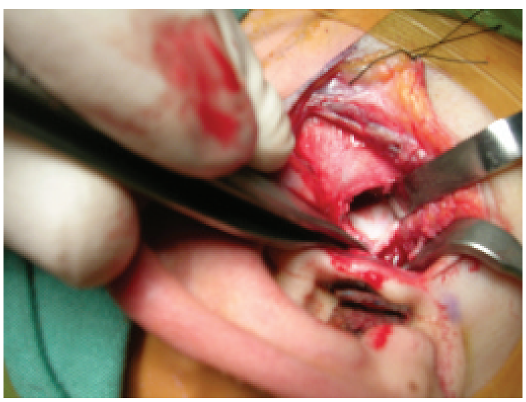


Figure 62.21 Surgical view of articular disc.

Buried horizontal mattress sutures (5-0 mersilene) are used to fix the disc to the remaining retrodiscal tissues in its new position (Figure 62.22). Various anchoring devices attached to the condylar head, such as the Mitek mini anchor, have also been reported as more stable fixation point for the disc.

2. *Discectomy*: In cases where the disc is found to be unsalvageable, it is completely excised. Both upper and lower joint spaces are exposed (Figures 62.14 and 62.18) and a vascular clamp is placed across the retrodiscal tissues (Figure 62.23). As the assistant distracts the mandible (and condyle) downwards and forwards, the posterolateral part of the disc is first excised with fine pointed scissors. The remaining anteromedial part of the disc is then clamped with Allis tissue forceps to help retract it laterally and posteriorly to facilitate excision of the remaining part of the disc (Figures 62.24 and 62.25). Infiltration with local anaesthesia and judicious diathermy of bleeding points will help reduce bleeding in the resultant joint cavity.

Many surgeons, however, leave the space empty following discectomy with good long-term results, whilst most other surgeons prefer to use pedicled temporalis muscle flaps.

Articular eminence

The articular eminence is often surgically remodelled in cases of recurrent dislocation. It may also be surgically altered to accommodate a fossa prosthesis during total joint replacement. Surgical procedures to the disc may also involve reduction of the articular eminence to facilitate the free movement of the operated disc. The articular

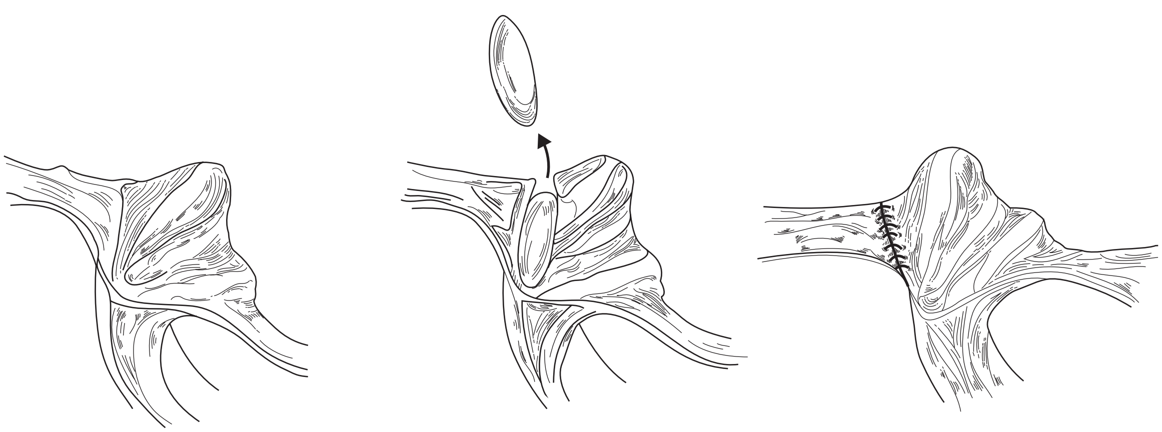


Figure 62.22 Excision of retrodiscal tissues (a) and (b) and posterior repositioning of disc (c).

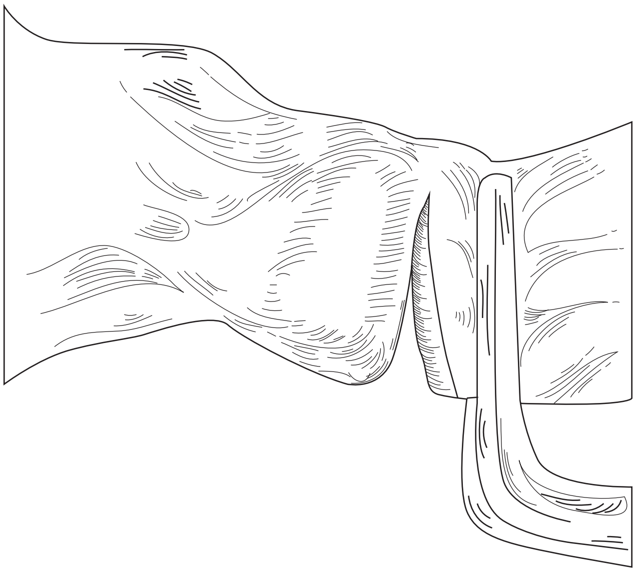


Figure 62.23 Partial excision of articular disc.

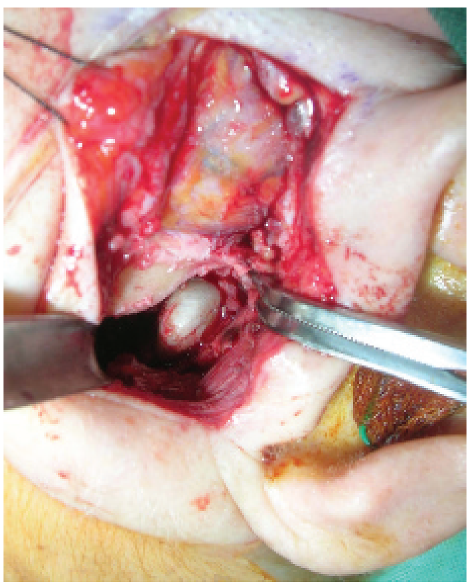


Figure 62.24 Exposed condylar head following discectomy.

Figure 62.25 Disc specimen.

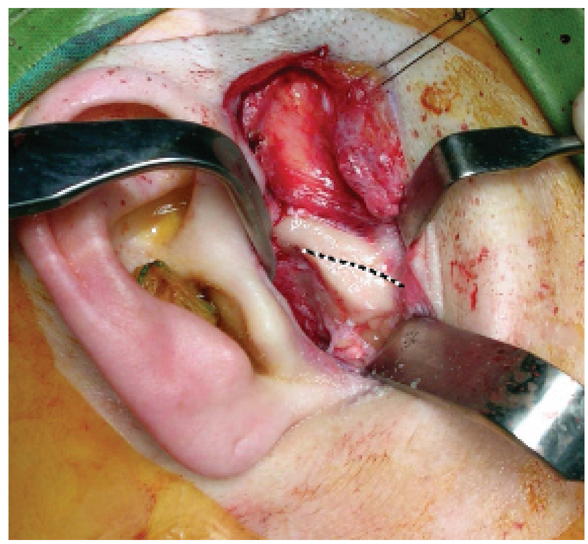


Figure 62.26 Dotted line showing osteotomy for eminectomy.

eminence may either be surgically reduced (eminectomy) or augmented with osteotomies and/or grafts.

1. *Eminectomy*: The base of the eminence is identified by scoring the bone with a fine bur in a horizontal line joining the anterior and posterior slopes (Figure 62.26). The lateral part of the eminence is best removed with a fine curved chisel (Figure 62.27). The medial extension of the eminence is not as prominent as the lateral part and so bone files mounted on a reciprocating powered handpiece can be used to reduce the bony prominence (Figure 62.28) until the glenoid fossa is flush with the root of the zygomatic arch.
2. *Eminence augmentation*: A number of augmentation procedures have been described to prevent the forward movement of the condyle in cases of recurrent dislocation. Unfortunately, the success of the following techniques is limited, especially where the condylar head is small or atrophic and may slip medial to the augmented site:
   a. *Dautrey's osteotomy*: This is where the zygomatic arch is divided just in front of the eminence and is then infractured. No fixation is used to hold the infractured arch which is held in position by friction alone (Figure 62.29).
   b. *Onlay graft*: Autogenous bone or allograft cartilage blocks are secured to the anterior slope of the eminence with miniplates and screws (Figure 62.30).

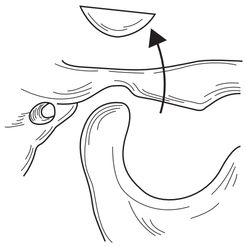


Figure 62.27 Eminectomy.

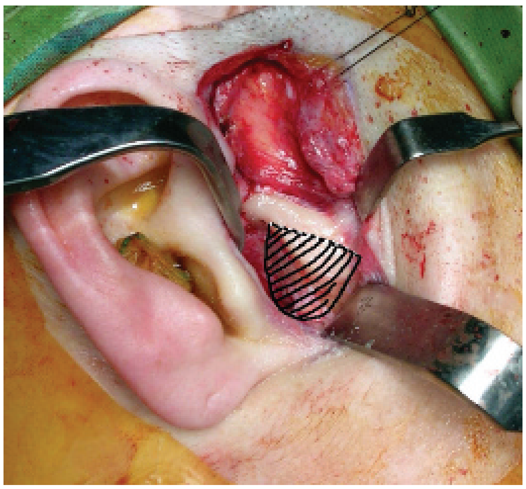


Figure 62.28 Shaded area showing bone removal required for eminence reduction.

c. *Interpositional graft*: A horizontal osteotomy is made along the base of the articular eminence. The inferior portion is downfractured and an autogenous bone graft is placed as an interpositional graft which is secured with bone plates and screws (Figure 62.31).

d. *Alloplastic fixation*: Metallic screws or plates are secured to the inferior surface of the eminence and left prominent to act as a physical barrier to the forward translation of the condyle.

Condyle

The condyle is pivotal to the development, form and function of the mandible. Trauma, disease or developmental disorders which afflict the condyle will also have a significant impact on the mandible, in particular, the occlusion. Surgery to the condylar head may range from simple smoothing of irregularities in the fibrocartilagenous articular surface, and removal of osteophytes, to complete amputation of the condyle itself in cases of severe disease or tumours. The following are some of the surgeries:

1. *Debridement*: Upon entering the lower joint space (Figure 62.18), close inspection of the condylar head may reveal irregularities or defects within the fibrocartilagenous articular surface (Figure 62.24). With the condyle inferiorly distracted, a Molt currette is used to gently shave the surface irregularities.
2. *Removal of osteophytes*: these bony projections are often found on the lateral pole of the condyle and should be removed with fine osteotomes rather than powered handpieces so as to minimize surgical trauma to the condyle itself.
3. *High condylar shave*: With the lateral pole of the condyle exposed, the top 5 mm layer is surgically removed with an osteotomy cut from the lateral aspect of the condylar head which is completed medially by chisel. The remaining surface is surgically smoothed with a bone file, ensuring there are no sharp margins around the circumference of the osteotomy site.
4. *Partial condylectomy*: The lateral pole of the condyle may be excised (Figure 62.32) with the deep margin up to half the width of the condylar head. The aim is to preserve the medial pole of the condyle in order

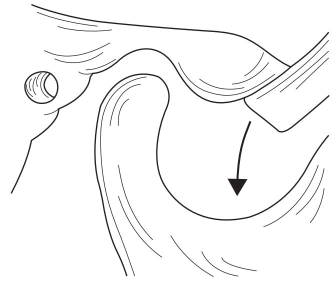


Figure 62.29 Downfracture of zygomatic arch to prevent forward translation of condyle.

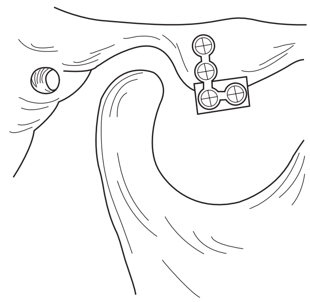


Figure 62.30 Augmentation of eminence with onlay grafts fixed with plate and screws.

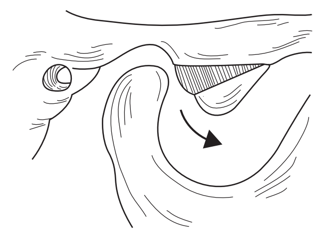


Figure 62.31 Augmentation of eminence by downfracture with interpositional grafting.

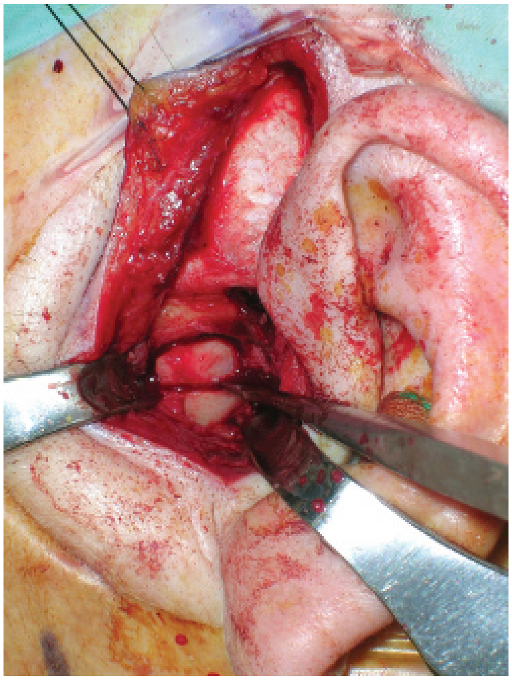


Figure 62.32 Osteotomy of condylar head.

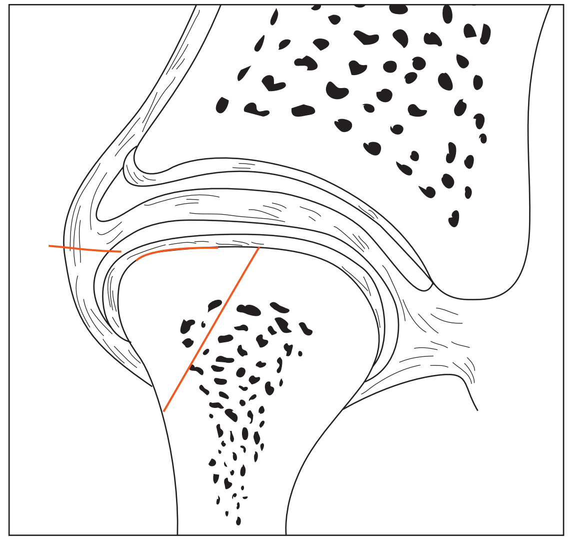
to maintain the height of the ascending mandibular ramus. A diagonal osteotomy is made from the posterior aspect of the condylar head (Figure 62.33) which is completed with chisels. Any sharp edges in the remaining defect are smoothly rounded with bone files.

5. *Total condylectomy*: Blunt dissection is carried inferiorly to expose the neck of the condyle to the level of the sigmoid notch (Figures 62.19, 62.20 and 62.34). With two condylar retractors helping to stabilize condyle, a reciprocating saw is used to section the condylar neck. A fine chisel is used to complete the osteotomy. The amputated condylar fragment is then held with bone holding forceps whilst the medial attachment of the articular disc is released with sharp scissors. Anteriorly, the thick attachment of the lateral pterygoid muscle is released with dissection scissors as a traction force is placed on the condylar fragment with the bone holding forceps. Once the condylar process is extracted (Figure 62.35) from its tissue bed, attention must be paid to the multiple bleeding sites.

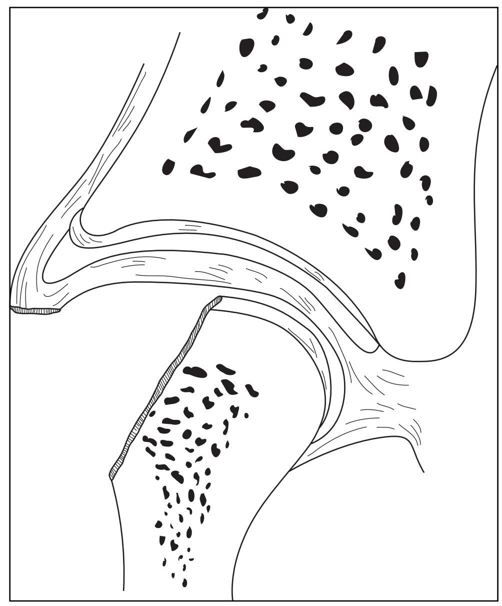
Total joint replacement with autogenous grafts or alloplastic prosthesis should always be considered at the same time as the condylectomy to prevent severe mandibular functional and structural deformity (see Chapter 64).

Gap arthroplasty

Gap arthroplasty is used for the management of TMJ ankylosis. Ankylosis release involves the removal of a



(a)



(b)

Figure 62.33 Sagittal ostectomy of lateral pole of condyle.

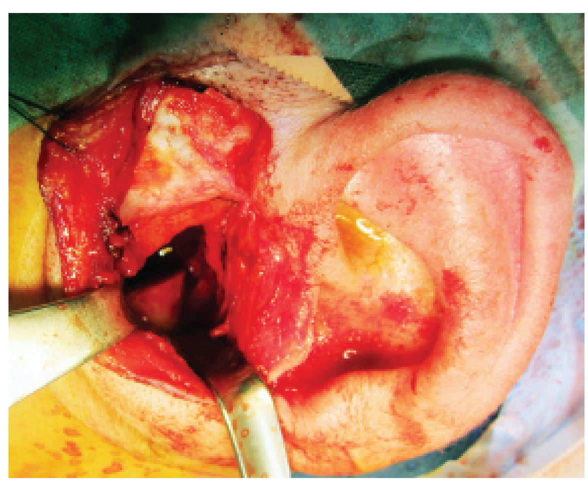
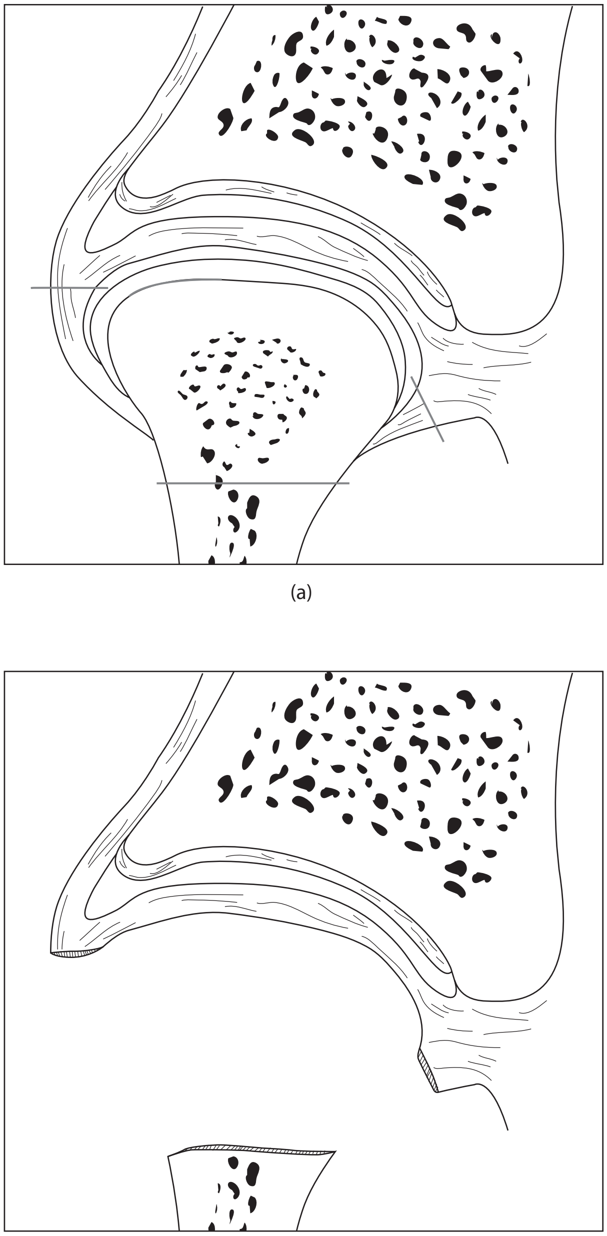


Figure 62.34 Osteotomy used for high condylectomy.



(a)

(b)

Figure 62.35 Ostectomy (a) and gap arthroplasty (b) for surgical release of TMJ ankylosis.

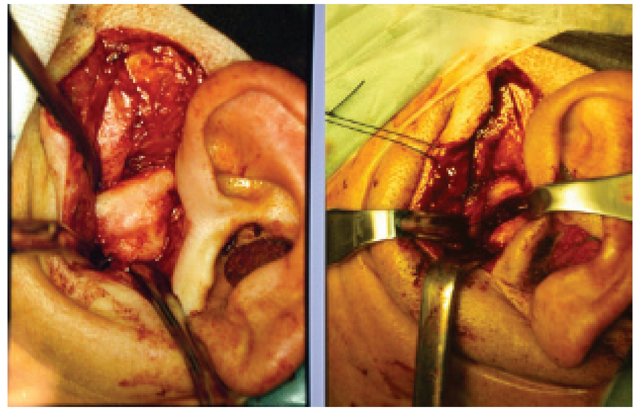
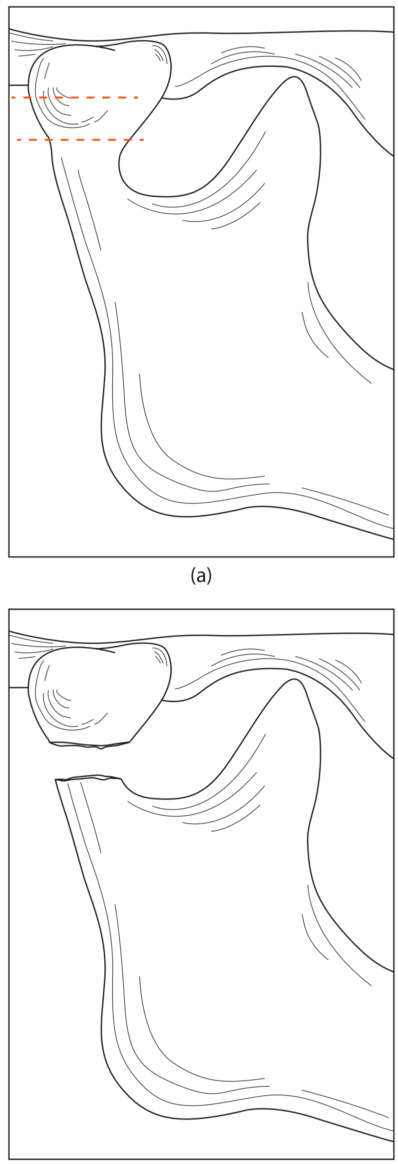


Figure 62.36 Bony ankylosis (left), following gap arthroplasty (right).



(a)

(b)

Figure 62.37 Line drawing of the Gap arthroplasty shown in Figure 62.36.

block of bone either the complete condyle (condylectomy) or full-thickness section of condylar neck which is referred to as a gap arthroplasty. The gap must be as wide as possible.

A new joint space is created below the original joint space (Figures 62.36 and 62.37) and an interpositional graft is inserted within the new joint space to prevent bone union or re-ankylosis. Due to loss of ramus height, some post-operative occlusal derangement occurs and, if performed bilaterally, an open bite results. The author uses abdominal dermis-fat graft to fill in the gap that is effective in preventing re-ankylosis and avoids the unsightly defect in the temple when a temporalis muscle flap is used.

Closure

Careful attention to haemostasis is essential prior to closure. The surgical wound should be repaired in layers, i.e. capsule, temporalis fascia, subcutaneous tissues and skin. Resorbable 4-0 sutures such as vicryl are used for the deep layers and 5-0 nylon may be used for skin either as simple interrupted (Figure 62.38) or subcuticular sutures that are removed after 7 days. A mastoid-type pressure dressing (Figure 62.39) is applied for 24 hours. The ear must be padded with gauze or cotton before placing the dressing. Drains are rarely indicated.

Figure 62.38 Interrupted nylon sutures.

Figure 62.39 Barrel head bandage used as pressure dressing for 24 hrs following TMJ surgery.

COMPLICATIONS OF TMJ SURGERY (ARTHROTOMY)

1. Poor patient selection
    a. Patient is an unreliable historian – secondary gain or compensation seeking
    b. Patient has unrealistic expectations of surgical outcome
    c. Psychiatric history
    d. Significant medical history
2. Inexperienced clinician
    a. Poor diagnostic skills
    b. Limited experience in TMJ surgery
3. Poor surgical technique
    a. Infection – haematoma, wound breakdown
    b. Bleeding
    c. Facial nerve paresis
    d. Scarring
    e. Deafness – middle ear surgically breached
4. Malocclusion
    a. Condylar resorption
    b. Overzealous arthroplasty and disc surgery
5. Limited mouth opening
    a. Adhesions
    b. Fibrosis
    c. Ankylosis
6. Persistent symptoms
    a. Failure to continue supportive non-surgical therapy
    b. Poor patient compliance – cannot follow instructions
    c. Misdiagnosis – chronic pain syndrome

Top tips

- The operating table should be slightly inclined with the head elevated above the level of the heart to help reduce intra-operative bleeding.
- A condom like rubber finger projection cut out of a urology drape is inserted in the mouth and taped to the lips to allow the surgical assistant to manipulate the mandible during surgery without desterilizing the surgical field.
- The skin/fascia flap should be developed down to the temporalis fascia which is preserved if the temporalis is not going to be used as an interpositional flap.
- Recovery is much quicker and morbidity is substantially reduced when the temporalis fascia overlying the temporalis muscle is left intact and not surgically breeched.
- Keeping a small periosteal elevator firmly on bone, the soft tissues enveloping the condylar process can be bluntly dissected off the condyle as far inferiorly as the level of the mandibular notch.
- The role of disc repositioning surgery has diminished in the light of the success of less invasive procedures such as TMJ arthroscopy and arthrocentesis.
- Bleeding is best controlled with a curved vascular clamp that is placed across the retrodiscal tissues immediately behind where the wedge excision of redundant tissue takes place (Figure 62.23).

- The author uses autogenous dermis-fat graft procured from the patient's lower abdomen to fill the resultant joint cavity.
- Aggressive debridement of articular cartilage must be avoided as this will result in severe remodelling of the condyle.
- Avoid using burrs to section the condyle and always use oscillating saws which do little harm to the surrounding soft tissues.
- Deliberately ignoring the original joint anatomy, a wide segment of ramus above lingula is resected, leaving the ankylosed mass attached to the base of skull (Figure 62.37).

SUGGESTED READINGS

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63

Treatment of temporomandibular joint ankylosis

ANDREW J SIDEBOTTOM

CONTENTS

TEMPOROMANDIBULAR JOINT ANKYLOSIS

Ankylosis or *anchylosis* (from Greek ἀγκύλος) is a stiffness of the articulation and rigidity of the bones of the joint, which may be the result of injury or disease such that movement is either not possible or is greatly restricted. With regard to the temporomandibular joint (TMJ), the disorder is usually classified as intra-capsular or extra-capsular according to where the restriction occurs. A particular type of extra-capsular ankyloses can occur when fusion takes place between the mandibular coronoid process and the adjacent zygomatic arch or maxilla.

The aetiology is usually due to trauma and/or infection although it can be the endpoint of degenerative or rheumatoid diseases, bone or other malignancy, repeated operation (iatrogenic) or agenesis of the joint. In the Western world, the usual cause of ankylosis is post-traumatic following intra-capsular condylar fractures or iatrogenic. These may result in ossification of post-traumatic fragments of bone, causing fusion between the mandible and the glenoid fossa.

MANAGEMENT

This should be considered according to the age of the patient affected.

Infancy

It is unusual to see ankylotic disease in the first few months of life. Agenesis, infection and birth trauma all may lead to fixity of the TMJ, as may overgrowth of the mandibular coronoid process. The aims of treatment in this age group are to restore movement and function, leaving reconstruction to later in life. Permitting mobility may allow functional growth and therefore early mobilization and may also permit decanulation where there is associated airway compromise requiring tracheostomy.

Childhood

Up to 15 ankylosis may be caused by trauma or infection (for example, from the middle ear or mastoid). As facial development is incomplete, joint fusion may also affect growth from the condylar growth centre leading to a deranged occlusion and marked facial asymmetry, with occlusal cant upwards and centreline discrepancy towards the affected side as maxillary growth is also impaired. Additionally, there will be loss of vertical ramus height with associated undergrowth of the maxilla.

Treatment is aimed at restoring function and movement of the TMJ with an associated attempt to prevent recurrence. This is usually achieved with a gap arthroplasty

and autogenous reconstruction often with a costochondral graft. Some lengthening of the ramus and occlusal levelling can be achieved by over-lengthening the ramus and controlling the eruption of the mandibular teeth orthodontically, permitting maxillary dentoalveolar growth on the ipsilateral side of the ankylosis.

Subsequent correction of any residual occlusal and cosmetic deformity proceeds in the late teens with bimaxillary surgery or in the early teens with the assistance of distraction osteogenesis of the mandible. Both techniques should level the occlusal cant and in the growth phase, this may be achieved by levelling the mandible and holding back mandibular dentoalveolar growth permitting maxillary dentoalveolar growth to correct the cant. This requires close orthodontic cooperation. Alternatively, secondary alloplastic reconstruction can achieve occlusal plane levelling with associated contralateral ramus osteotomies and maxillary osteotomy to level the occlusal plane.

Adults

Ankylosis in this age group (where dentofacial development is complete) is usually the result of trauma, inflammatory arthropathy or multiple previous procedures. Treatment is aimed at restoration of satisfactory movement and function and prevention of recurrence. Rare occlusal discrepancies are dealt with by standard orthognathic surgery, although an anterior open bite and other mandibular mal-alignments may be corrected during joint replacement surgery, possibly with associated orthognathic surgery.

INVESTIGATIONS

Routine clinical assessment should be supplemented with adequate imaging of the degree of ankylosis. This is best achieved with computed tomography (CT) scanning, preferably with 3D reformatting. Vascular assessment of the infra-temporal fossa may require magnetic resonance angiography to determine the extent of involvement of the maxillary artery and great vessels. The ankylotic process may extend widely and it is important to determine the extent and risks of the procedure pre-operatively to adequately prepare and consent the patient. In addition, patients with ankylosing spondylitis and rheumatoid arthritis may need respiratory and spinal assessment. Modification of their drug regimes may also be required.

ANAESTHESIA

These patients require specialist anaesthetic services with capability to provide fibre-optic intubation as their mouth opening is so restricted. This can be guided with the aid of the CT scan showing access to the nasal passage. If this is not possible then pre-operative tracheostomy may be required either in the standard open fashion or by a percutaneous dilatational technique. Weight loss and dietary compromise may also be an issue, which may require pre-operative enteral feeding to supplement oral intake. Hypotensive anaesthesia aids the dissection particularly of the deep tissues and an anti-Trendelenberg table (30° head up) with no neck flexion will also reduce venous filling.

SURGERY IN THE CHILD

The aim of treatment in the child is not only to regain mobility and function but also to permit ongoing growth. For this reason, prosthetic joint replacements are usually contra-indicated in the child and autogenous reconstruction is preferred. Several clinicians are now investigating whether secondary functional growth occurs following adequate mobilization and alloplastic reconstruction, although this remains controversial. Costochondral and sternoclavicular grafts permit the possibility of ongoing growth although this is unpredictable. In addition, they are more likely to re-ankylose and the patients and parents should be warned of these possibilities. Should the graft fail later in life (post-puberty) it should be converted to a prosthesis. Alternatives include simple gap arthroplasty, temporalis interposition, dermal grafts and free bone grafts. The stability of these grafts is limited and growth will not occur leading to the need for secondary reconstruction later in life. The advantage is less morbidity at the first procedure resulting in less morbidity in subsequent reconstructions.

SURGERY IN THE ADULT

The aim of treatment is to restore adequate movement of the TMJ. Extra-articular ankylosis, such as that due to fusion of the coronoid process, may require simple intra-oral coronoidectomy, possibly with trimming of bone from the upper point of fixity – zygomatic arch or maxilla.

Prosthetic replacement of the TMJ is now the gold standard in developed countries for restoration of function of the TMJ following ankylosis surgery. It provides a good 'gap' of greater than 1 cm and good function in the immediate post-operative period with the additional use of a Therabite device as patient provided passive motion. It reduces the risks associated with the harvest of a costochondral graft and reduces hospital stay, with low morbidity and a predictable long-term outcome.

RESECTION OF THE ANKYLOTIC TISSUE

The patient should rinse their mouth in the anaesthetic room with chlorhexidine mouthwash to reduce intra-oral colonization. Preparation of the patient involves shaving the temporal region to provide a clean field for wound closure without the intervention of hairs. The patient is

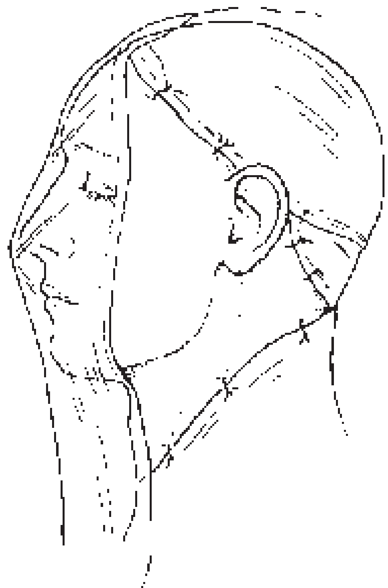

Figure 63.1 Draping of the patient prior to joint replacement.

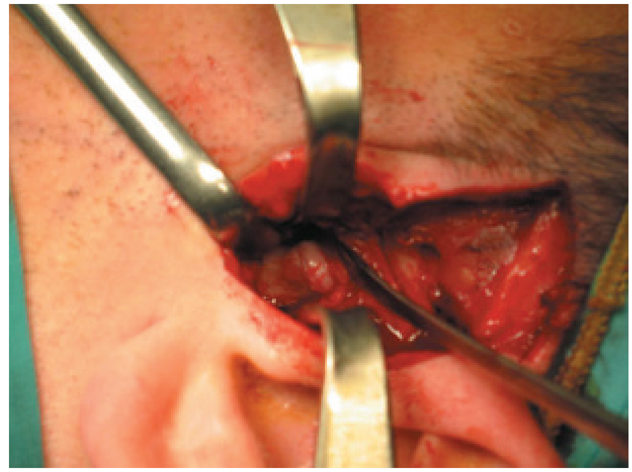

Figure 63.2 Exposure of the condyle of the mandible.

placed in a stable head ring (Rubens pillow) with the nasal tube secured in the midline over the patient's forehead. Skin preparation should be carried out with Betadine. Draping should cover the mouth separately as during the procedure the occlusion will need to be secured. The anaesthetic tube may be most safely secured using a clear adhesive dressing (such as op-site), although this should be left clear of the mouth. Two of these can be used in a bilateral case with the mouth free in the middle for intra-operative access. The face is left clear of the other drapes to permit visualization for 'twitching' of the facial nerve during the procedure (Figure 63.1). The ear canal is cleansed and covered with op-site.

Upper and lower arch bars or other means to achieve intermaxillary fixation should be placed at this stage if access permits with the face covered with a separate towel. All instruments used in this stage of the procedure should be kept separate to maintain sterility of the facial operation site. Gowns and gloves are changed, the incision sites are marked and injected with local anaesthetic containing adrenaline to reduce oozing. Five minutes should be allowed for it to take effect.

Upper approach

The joint is approached via a pre-auricular incision with temporal extension to gain access to the capsule. The capsule of the joint is opened with a vertical incision along the posterior border of the condyle and at the level of the disc from the base of the zygomatic arch. Bipolar diathermy should control any haemorrhage during this dissection. The anterior and posterior borders of the condylar neck are exposed in the sub-periosteal plane and the condylar neck exposed with the aid of Dautrey, Wolford or similar retractors (Figure 63.2). This permits the lifting of the periosteum from the posterior surface of the condylar neck as the maxillary artery lies a few millimetres deep to this area (with the mandibular division of the trigeminal nerve emerging from the foramen ovale just deep to this).

Lower dissection

There are various approaches to the ramus of the mandible. The submandibular approach, whilst safe stretches the tissues somewhat and makes the upper dissection of the condylar neck difficult to achieve. The Kent modification of this approach described in the first edition of this book reduces the stretching whilst providing excellent access to the ramus. It does increase the risk to the marginal mandibular division of the facial nerve, but allows easier access to the external carotid artery in cases of vascular catastrophe. The author prefers a retromandibular access. Whilst this carries risk of damage to the marginal mandibular branch, this has not persisted in primary cases as any branches traversing the wound can be seen and retracted if blunt dissection is used through the parotid. It provides a rapid access and permits access to the external carotid and retromandiblar vein if required.

The periosteum of the posterior border of the ramus is incised continuing along the lower border to release the pterygomasseteric sling and sub-periosteal dissection is continued to expose the lateral and posterior surfaces of the ramus up to the sigmoid notch and to join the superior dissection. A sigmoid notch retractor is useful and a swan neck retractor around the posterior border of the ramus permits exposure of the condylar neck from below whilst maintaining the closely related vessels out of the surgical field.

A proximal condylectomy from above reduces the amount of bleeding when removing this fragment although it may be easier to complete the condylectomy from below as the periosteum on the medial surface of the condylar neck is easier to retract without stretching the

temporal branch of the facial nerve from above. The use of a piezo saw reduces the risk of bleeding and is particularly useful in ankyloses cases due to the proximity of the deeper vessels. If using a drill, the initial cut is marked by postage stamping in a 45° angle from the sigmoid notch postero-inferiorly to the posterior border of the ramus. This should be completed on the lateral cortex but the inner cortex should be left intact to permit final separation of the condylectomy by insertion of a broad periosteal elevator (such as a Howarth) to prevent inadvertent drilling or osteotome placement through the medial periosteum into the maxillary or masseteric vessels. In any case as much of the medial tissues as possible are held away sub-periosteally by retraction. The lower portion of the resection is now complete and removal of the residual ankylotic mass can now proceed, mostly from above.

Removal of the ankylotic mass

This stage of the procedure is different in every patient and only general guidelines can be given. The ankylotic mass can extend a long way along the base of the skull and therefore resection may be compromised by cranial nerves emerging from the skull base, the maxillary, middle meningeal and ultimately internal jugular and carotid vessels. It is for this reason that pre-operative vascular imaging may be useful and the assistance of a vascular or skull base surgeon may be required.

The upper limit of the ankylosis may be defined by a fine line in the bone exaggerated by either pulling down on the ramus prior to making the condylar cuts or by using a Juniper distractor across the joint. This may facilitate one plane of the upper dissection. Once the lower condylectomy cut is made then the periosteum should not be transgressed. Although the condylectomy cut may generate some mobility, do not be tempted to pull on the fragment as this may avulse some deeper structure and haemorrhage control down a deep dark hole can prove troublesome! Proceed to carefully dissect around the mass anteriorly and posteriorly with the aid of bipolar diathermy to maintain a clear operative field. Using the upper plane as an initial guide to deeper drilling helps to reduce the risk of intracranial perforation. Carefully remove as much as possible of the mass until ready to fashion a new glenoid fossa. This may be a piecemeal process if the mass does not readily come out intact.

The mouth opening should be assessed at this stage. According to the Kaban's guidelines if opening is less than 30 mm an ipsilateral coronoidectomy should be performed. Following this if opening remains below 30 mm a contralateral coronoidectomy should be performed. Whilst the former can be achieved through the operative wound, access to the contralateral side can be achieved perorally as described elsewhere. When required, coronoidectomy can be achieved by direct vision either via the upper or via the lower approach (Figure 63.3). Smooth all

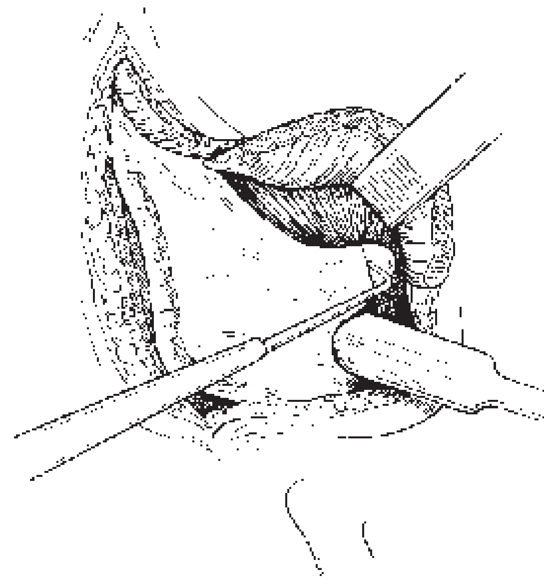

Figure 63.3 Coronoidectomy can be carried out under direct vision.

the remaining bone surfaces prior to accepting the final defect and irrigate the wound to remove bone debris which may predispose to re-ankylosis. At this stage, it is useful to place a finger in the wound to palpate for any bony interferences. Also check that the joint is fully mobilized and that haemostasis is satisfactory. The defect is now ready for reconstruction.

The mouth can now be thoroughly examined and any dental or periodontal condition dealt with. If the occlusion has been deranged by the disease process, once mobility has been assured, the teeth can be placed in the desired occlusion and held with temporary inter-maxillary fixation. In edentulous patients, gunning splints may be used. If there has been maxillary underdevelopment in a child then an intermediate wafer providing space for levelling the occlusal plane with ongoing alveolar growth may also be used. Gown and gloves are again changed, ensuring that the instruments used in the mouth do not contaminate the facial operative field.

At this stage in the procedure, the method of reconstruction varies between the child (costochondral graft) and the adult (prosthetic joint replacement). Following completion of the reconstruction abdominal free fat may be packed around the reconstruction just prior to wound closure This may help to reduce the risk of recurrence of the ankylosis.

COSTOCHONDRAL GRAFTING

This provides the main alternative to total joint replacement in the adult, but is a second option in the authors' opinion due to the risk of re-ankylosis, overgrowth or collapse. One of the pre-requisites to management in the adult

is to achieve an adequate gap between the bone surfaces. On occasion, the costochondral graft may be preferred due to either local factors such as a heavily irradiated bed, allergy to implant materials (although titanium only prostheses can now be produced), lack of surgical expertise to perform prosthetic replacement or financial factors where a prosthesis is refused due to cost. Microvascular grafting may be considered although this adds considerably to operative time and complications and has the same potential for re-ankylosis for the same reasons as costochondral grafting. Certainly where multiple previous procedures have been performed the revascularization of costochondral grafts will be limited whilst alloplastic reconstructions do not share this issue.

In the child, costochondral grafting remains the management of choice as a prosthesis cannot grow with the child and would inevitably require revision at cessation of growth. There has been limited evidence of functional growth following alloplastic reconstruction although at present this remains a controversial primary reconstruction option in the child. Costochondral grafts can permit ongoing growth, although this is unpredictable. For these reasons, the technique for costochondral grafting in the child will be described. The approach in the adult follows the same choices of access to the mandible as for resection of the ankylotic mass. In the child, a lower cervical incision may be considered as with growth this may rise towards the lower border of the mandible and if initially too high, ultimately end as a scar on the face. Alloplastic reconstruction is described in Chapter 64.

COSTOCHONDRAL GRAFT HARVEST

In the child, usually a contralateral rib provides the best curvature with the left rib being used for the right side and vice versa. The patient and anaesthetist should be warned of the possibility of pleural puncture and therefore, the necessity for chest drainage post-operatively and difficulties with oxygenation intra-operatively.

In the female with breast development, the incision should be made directly below the breast skin fold. This leaves an almost invisible scar which in any case is cosmetically more acceptable. In the male, the approach should be lower and aimed at the sixth or seventh rib. The incision should follow the line of the ribs (Figure 63.4) unless guided by the infra-mammary fold, and dissection is continued to the rib periosteum. Meticulous haemostasis permits better visibility and at this stage, the periosteal envelope should be preserved. Carry the dissection under the periosteum commencing at the maximum curvature of the rib and developing the plane inferiorly, ensuring the preservation of the neuro-vascular bundle which lies on the inferior surface of the rib. Raise the periosteum superiorly (Figure 63.5) until continuity with the lower dissection is achieved. It may then be possible to insert a Doyen retractor initially to retract and subsequently elevate the periosteum.

The incision through the periosteum should now be continued towards the costochondral junction. About 1 cm from this junction makes the incision diverge in a ‘Y’ fashion, continuing onto the cartilage side to bring the incision edges back together and to complete a ‘diamond’ shape. The cartilage may then be incised, with the remaining periosteum helping to maintain continuity with the rib and thus the costochondral junction. Finally, the length of rib required should be determined. The inner dissection is continued with a curved rib raspatory (Figure 63.6) or Howarths and the lateral rib cut completed with a curved rib cutter (Figure 63.7). The rib is harvested and placed in saline soaked gauze. Check for a pleural tear by pouring saline into the wound and looking for bubbles prior to closure. If present, a chest drain should be placed in the usual manner in the midclavicular line. The wound is closed in layers with deep resorbable sutures to the periosteum to aid rib regeneration. Vacuum suction drainage can be placed above this layer and the skin is closed.

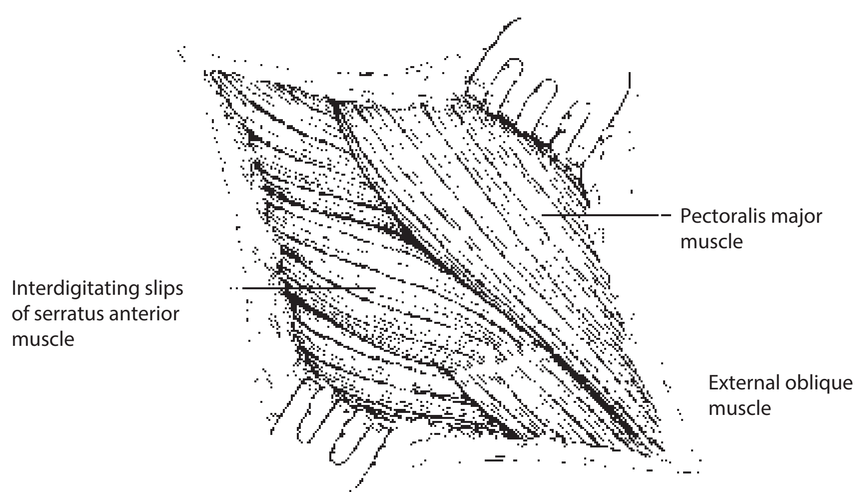

Figure 63.4 Exposure of the superficial chest wall muscles.

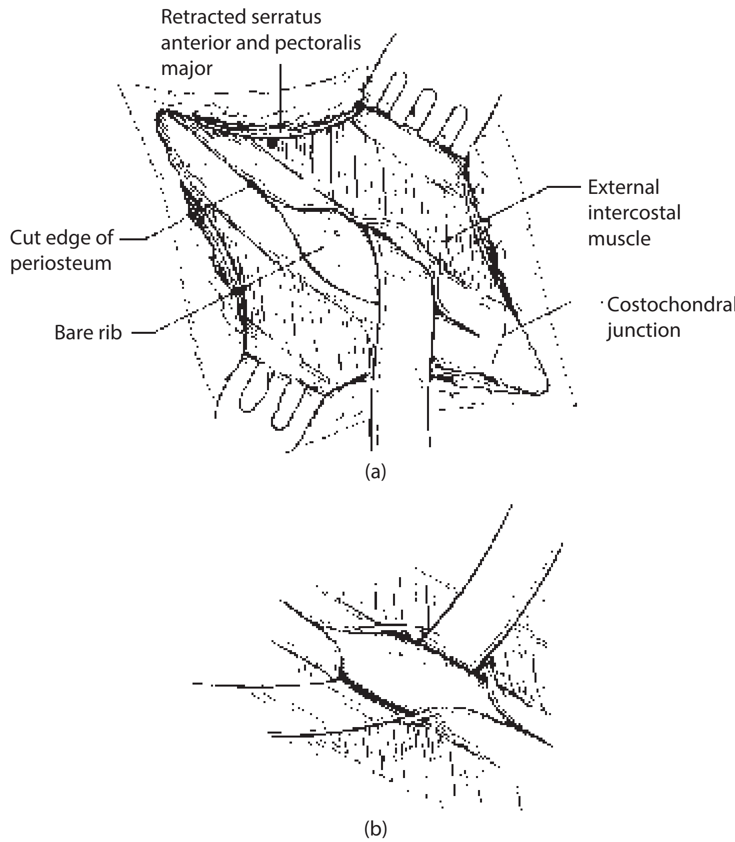

Figure 63.5 Sub-periosteal dissection of the rib towards the costochondral junction with retraction of the pleura on the deep surface.

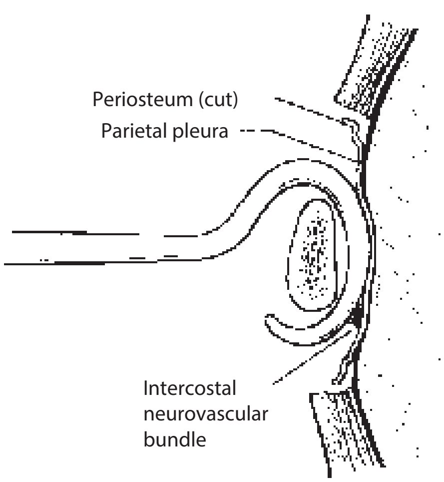

Figure 63.6 The inner dissection is continued using a curved rib raspatory taking care to preserve the pleura.

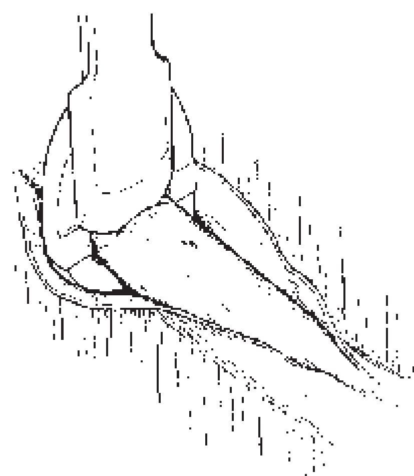

Figure 63.7 The lateral rib cut is completed with a rib cutter.

RECONSTRUCTION

The rib is trimmed and a temporalis fascial interposition graft may be placed prior to rib fixation with the cartilage portion in the glenoid fossa (Figure 63.8). The rib is held with either cortical screws or plates to the lateral border of the ramus in the desired position (Figure 63.9). The lateral aspect of the mandible may be pre-prepared to enable direct fixation of the rib to cancellous bone permitting a more accurate fit. The rib may also be greenstick fractured to permit more accurate adaptation. The wound is closed in layers over suction drainage.

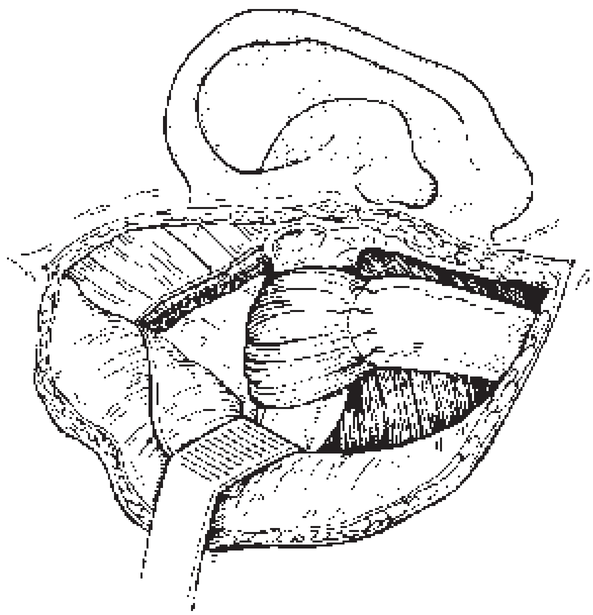

Figure 63.8 The costochondral graft in situ with temporalis interposition.

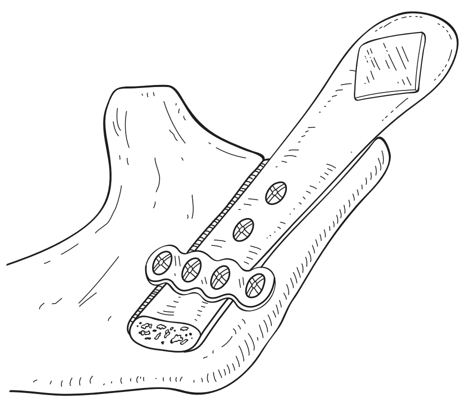

Figure 63.9 The costochondral graft is secured to the mandible with miniplate or bicortical screws.

CONCLUSION

Management of ankylosis requires a collaborative approach with the anaesthetic team to provide a secure airway during surgery. Resection of the ankylosis should be performed carefully with due attention to the associated neurovascular structures on the medial surface. An adequate gap should be achieved prior to appropriate functional reconstruction and adequate mouth opening should be achieved, if necessary combined with coronoidectomies. Post-operative physiotherapy is essential to maintain the opening achieved intra-operatively and ideally should commence in the first post-operative days. This is facilitated when an alloplastic reconstruction is used. Subsequent follow-up should be at least 10 years to check for recurrence and manage this early.

Top tips

- Ankylosis of the TMJ is an uncommon problem in the Western world and should only be dealt with by a surgeon with experience in this area. The surgeon should have experience with the various approaches and methods of reconstruction and access to a neurosurgeon.
- Consider pre-operative vascular imaging in patients with extensive ankylosis or several previous procedures as the vessels can lie in the ankylotic mass.
- Access to the carotid can be achieved by deepening the retromandibular wound onto digastric and anterior to the sternocleidomastoid muscles.
- Always group and save these patients as blood loss can be sudden and catastrophic.
- Rapid access to the joint is facilitated by the pretemporal fascial dissection approach.
- If inadequate opening is achieved intra-operatively consider coronoidectomy.
- Ensure adequate mobilization post-operatively by regular use of the Therabite device.

SUGGESTED READINGS

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64

Total prosthetic replacement of the temporomandibular joint

ANDREW J SIDEBOTTOM

CONTENTS

Total replacement of the temporomandibular joint (TMJ) has been an option since the nineteenth century, but the recent prosthetic choices arose following the development of the Christensen prosthesis in 1963. Initially, these were individually made prostheses of cobalt–chromium alloy fossa and ramus component with an acrylic condylar cap. Subsequently, this prosthesis was standardized and remained one of the prostheses of choice until the conversion of the condylar cap to an all cobalt–chromium condylar component in 1997 to give a metal-on-metal prosthesis. The Christensen prosthesis was removed from the market and there are currently two commonly used prostheses available on the UK market as either a stock or custom-made variants (TMJ Concepts and Biomet). Hemiarthroplasty using the Christensen prosthesis has also been used although this seems to fail over the medium term of 5–10 years requiring revision to a total joint prosthesis due to condylar head wear.

During the 1970s, the Kent prosthesis (VK I) came into and went out of vogue due to the reaction of this prosthesis' proplast-teflon component (on the fit surface of the prosthesis) to the surrounding tissues causing destructive osteolysis and making revision of these prostheses extremely difficult. The adjusted VK II prosthesis, although successful, was withdrawn due to the litigation associated with its predecessor.

Techmedica developed a titanium ramus prosthesis with a cobalt–chromium condylar head and a titanium-based high-molecular weight polyethylene fossa in 1989. This company was taken over and the prosthesis is now made by TMJ Concepts. This is a custom-made prosthesis and is currently the authors' first choice of prosthesis. It requires a Protomed 3D CT scan to create a CAD–CAM model on which the surgical cuts are determined and the prosthesis is subsequently made. The construction technique can be seen from the illustrations (Figure 64.1). In patients with component part allergy to cobalt–chromium alloy, an all titanium condylar component can be constructed although the wear characteristics of a hardened titanium surface are less certain than cobalt–chromium alloy. The prosthetic fit is superior with a custom-made prosthesis compared to a stock prosthesis and therefore less mobility in theory should lead to better success rates based on simple orthopaedic principles.

Biomet (formerly Lorenz) make a stock and custom prosthesis with similar components to the Concepts system (Figure 64.2). The Concepts system fossa has a titanium mesh back, whereas the Biomet fossa is all ultra-high-molecular weight polyethylene. The Biomet stock prosthesis has five choices of ramus component and three choices of fossa size. This requires eminoplasty to permit the fit of the fossa and is hence a less accurate fit suggesting the possibility of micromotion, which in orthopaedic terms is one of the causes of failure. It also requires accurate pre-operative assessment of the ramus and base of skull anatomy to determine whether the ramus component will actually fit against the fossa component, as varieties of ramus yaw and fossa lateral and sagittal angulation may not permit this to occur in a proportion of cases.

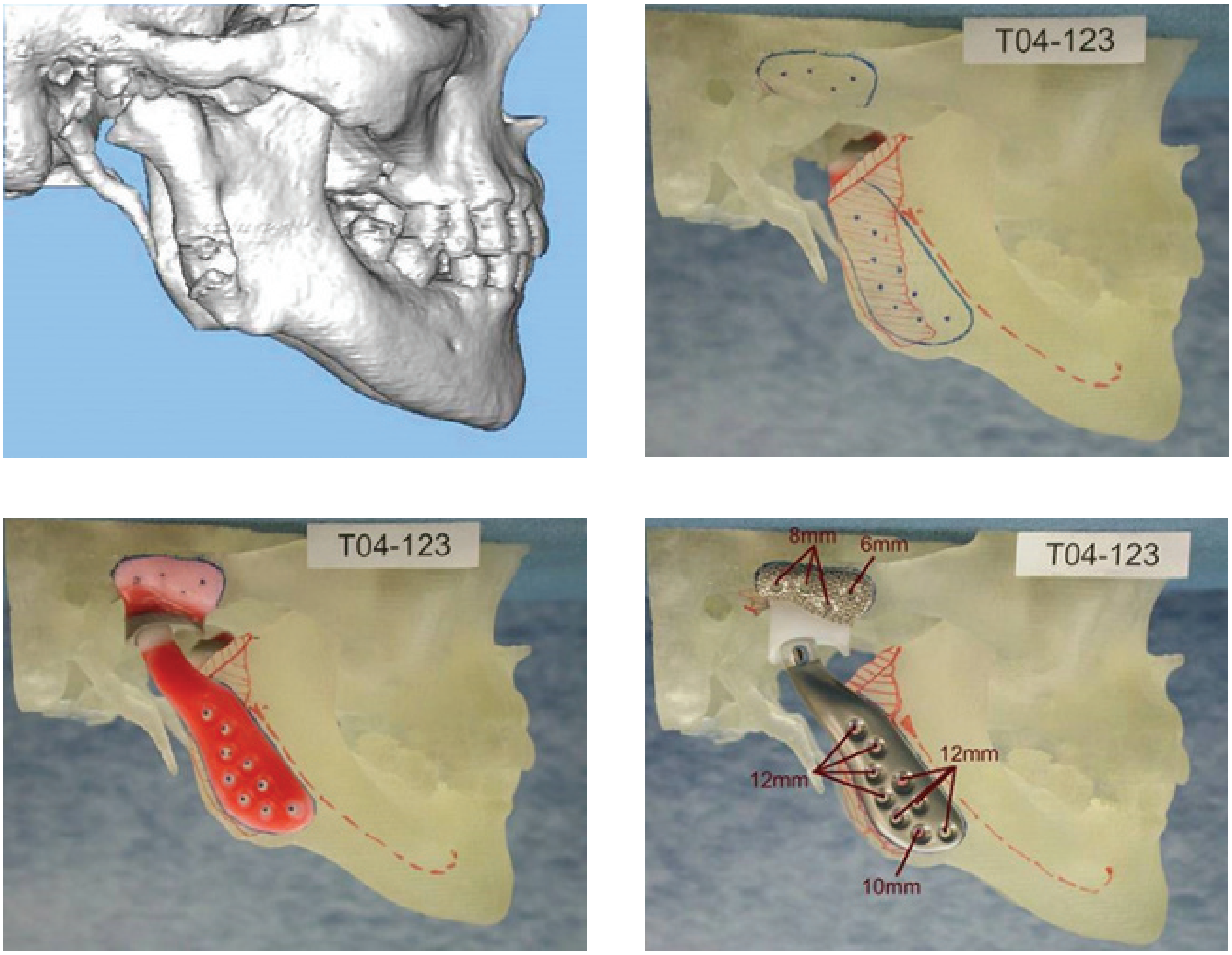

Figure 64.1 Illustration of three-dimensional model, resection, wax up and prosthesis on model using the TMJ Concepts prosthesis.

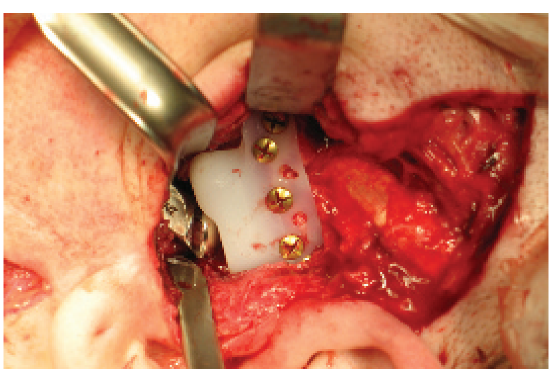

Figure 64.2 Biomet prosthesis in situ.

The issues of metal-on-metal prostheses with a glide component in both orthopaedic knee implants and latterly with the Christensen metal-on-metal have led to the abandonment of this type of prosthesis in orthopaedic devices. The cause of these problems are not clear, but may be related to implant allergy at the time of placement or its development during implant wear and exposure to component wear particles. Around 10% of the general population are nickel allergic with less than 1% allergic to the other alloy components and a type 4 hypersensitivity reaction may develop in allergic individuals. There may also develop an immune-mediated response to wear debris. Approximately 10% of metal-on-metal TMJ prostheses in a UK series have failed and been found to have a giant cell foreign body reaction surrounding them.[1] For this reason, it is essential that all patients are at least patch tested for allergy to nickel, cobalt, chromium and molybdenum individually and if necessary proceeding to lymphocyte transformation testing prior to recommending a cobalt–chromium alloy-based prosthesis. Unfortunately, at time of publication titanium only prostheses cannot be routinely used as they are not Food and Drug Administration (FDA) approved and a suitable indication for their use needs to be demonstrated, although the 1 year outcomes of both prostheses are similar.[2]

CHOICE OF PROSTHESIS

Prosthetic choice depends on indications, presumed benefits, personal preference and cost. Whilst there are good long-term outcome studies for both the Biomet and Concepts prosthesis (90% or more long-term survival) these studies should be taken in the light of studies involving orthopaedic implants. The long-term Christensen studies utilized the acrylic condylar head, which has now been discontinued due to excessive wear leading to anterior open bite formation after 15–20 years. These studies cannot be correlated with the newer metal-on-metal Christensen introduced in the late 1990s. Likewise, although the outcomes for the custom-made Concepts prosthesis are even more impressive, they only extend to 20 years at present.[3] The outcomes for total knee replacement persist to 15 years but then deteriorate due to wear and it remains to be seen whether this will also be the case for the metal on high-molecular weight polyethylene TMJ prostheses (TMJ Concepts and Biomet). Patients should be warned of the possibility of long-term failure and for this reason prosthetic replacement should only be considered as a last resort according to National Guidelines[4] and should only be used by high-volume surgeons aware of the complications of insertion in order to give the best possible outcomes. Revision surgery carries more significant risk of morbidity particularly related to the facial nerve, and certainly should only be contemplated by an experienced surgeon. TMJ replacement is not for the occasional surgeon as suggested by the UK NICE (National Institute for Health and Care Excellence) guidelines.

INDICATIONS AND CONTRAINDICATIONS

The indications and contraindications for total replacement of the TMJ published by a UK consensus study group[5] can be seen in the tables. The indications for surgery are more stringent than for an orthopaedic total joint replacement (Table 64.1). It is essential, prior to consideration of prosthetic replacement, that an appropriate trial of conservative management (including arthroscopy if possible) has been attempted and failed. Diagnosis of condylar disease should be made with the aid of computerized tomography (CT) or magnetic resonance imaging (MRI) scan as a minimum (not just plain radiographs). CT scan is preferable as it shows the bony anatomy in more detail and is required using a Protomed protocol (3D) if a custom made prosthesis is to be constructed.

The clinical indicators (Table 64.2) give an idea of the severity of disability of the patient (similar to walking distance for total hip replacement) and also permit assessment of outcome following the procedure. Contraindications are rare (Table 64.3) but include severe local infective process or radiation reaction or associated severe immune compromise. These are relative, however, as most rheumatoid patients are on disease modifying drugs, and with appropriate short-term adjustment of medication, prosthetic replacement can be safely carried out with minimal added risk. Bisphosphonate use does not seem to cause any issues.

Dental status should be checked pre-operatively and any teeth restored with compromised teeth being removed. Post-operative dental infection risks prosthetic biofilm infection with the required removal of the prosthesis. Revision surgery carries a significant increase in morbidity in addition to the cost of around US$10,000 per prosthesis. Any dental infection post-operatively should be dealt with aggressively, preferably with extraction. Prophylactic antibiotics are recommended according to the American Association of Orthopaedics guidelines for invasive dental procedures for the 2 years following prosthetic insertion.

Table 64.1 Indications for total prosthetic replacement of the TMJ

Disease processes (involving condylar bone loss)
Degenerative joint disease/Osteoarthrosis
Inflammatory joint disease (rheumatoid, ankylosing spondylitis, psoriatic)
Ankylosis
Post-traumatic condylar loss/damage
Post-surgical condylar loss (including neoplastic ablation)
Previous prosthetic reconstruction
Previous costochondral graft
Major congenital deformity
Multiple previous procedures

Table 64.2 Clinical indicators for total prosthetic replacement of the TMJ

Usually a combination of the following
Dietary score of <5/10 (liquid scores 0, full diet scores 10)
Restricted mouth opening (<35 mm)
Occlusal collapse/anterior open bite/retrusion
Excessive condylar resorption and loss of vertical ramus height
Pain score >5 out of 10 on visual analogue (in combination with any of above)
Quality of life issues other than above

Table 64.3 Contraindications to total prosthetic replacement of the TMJ

Contraindications
Ongoing local infective process
Severe immune compromise
Severe ASA 3 disease processes (relative)

SURGICAL TECHNIQUE

Intravenous antibiotic prophylaxis aimed at the common skin commensals should be given on induction and continued for 24 hours intravenously with 5 days orally post-operatively. Catheterization will aid in fluid monitoring, but should aim to be removed at the end of the procedure. Hypotensive anaesthetic techniques and a head up table help to reduce blood loss peri-operatively.

The standard pre-auricular and retromandibular approaches to the TMJ are adopted. The patient is anaesthetized with a centreline tube extending over the vertex of the head (see Chapter 63). Consideration of anaesthetic technique should be borne in mind when planning surgery as fibre-optic aided intubation or tracheostomy may be required due to restricted mouth opening. Arch bars are placed and the operating field around the mouth kept totally free from contaminating the operating field of the prosthetic replacement. The mouth is covered by the opsite free ends (see Chapter 63) and local analgesic with adrenaline is infiltrated into the pre-auricular and retromandibular incision sites. The joint is exposed from below and above (see Chapter 63). The required condylectomy is carried out and the soft tissues of the capsule, disc, lateral pterygoid and periosteum dissected gently with copious diathermy to maintain a blood-free field, whilst trying not to extend the dissection too far medially where the maxillary, middle meningeal and masseteric vessels and the mandibular division of the trigeminal lie within a few millimetres. It is essential that all disc and capsular tissue is removed to provide sufficient space for the prosthesis. Residual disc tissue in particular may interfere with prosthetic function and the disc can be removed most safely with the aid of diathermy and subsequent scissor freeing from the lateral pterygoid, which tends to ooze if just cut. If adequate mouth opening (>30 mm) is not achieved the coronoidectomy can be completed through either the superior or inferior wound under direct vision. Contralateral coronoidectomy may also be required if opening still does not exceed 30 mm.

Once the fossa is completely cleared of soft tissue the prosthetic fossa is tried in. The fossa is irrigated with gentamicin containing saline and the fit of the prosthesis checked and if necessary the fossa adjusted if there is any rocking. The different types of prosthesis require slightly different techniques at this stage and will not be further described. The following will be a description of the technique of placement of a custom-made prosthesis.

The fit of the fossa is confirmed. The patient is placed in intermaxillary fixation (IMF) to the desired occlusion and then all gowns and gloves are changed and the instruments for the intraoral procedure kept totally separate. The fossa is again trialled to ensure that adequate condyle and coronoid have been removed to enable free fitting of the fossa and rotation of the condylar component on mouth opening. There should be at least a 5-mm gap between the prosthetic fossa and the mandibular stump. The cavity is again irrigated with gentamicin solution and the fossa fitted and secured with usually 3–4 screws into the zygomatic arch.

The lower incision is now entered and the fit of the condylar component checked. It may be necessary to smooth down the lateral border of the mandible according to the pre-operative planning on the CT model. This has usually been necessary at the mandibular gonial angle due to eversion of the bone tissues in this area at the lower attachment of masseter. Once the fit to the lateral border has been confirmed, the fit into the fossa component is confirmed. This should match that seen on the photos of the prosthesis on the model (Figure 64.3). Usually it lies about 1/2 to 2/3 of the way into the fossa. If the head lies too superficial to this it suggests that insufficient condylar neck has been removed and this can be confirmed by direct vision and usually the prosthesis will rock in the supero-inferior plane. If necessary more condylar neck can be removed with extreme care not to damage the in situ fossa prosthesis. If necessary this should be removed prior to further bone removal.

Once the fit of the condylar prosthesis is confirmed this is secured initially with three screws to the length marked on the diagrams supplied by the company. The IMF is removed and the occlusion is checked. If this is not correct the position of the prosthesis requires adjustment. Once the position and occlusion are correct, at least five bicortical screws should be inserted using copious

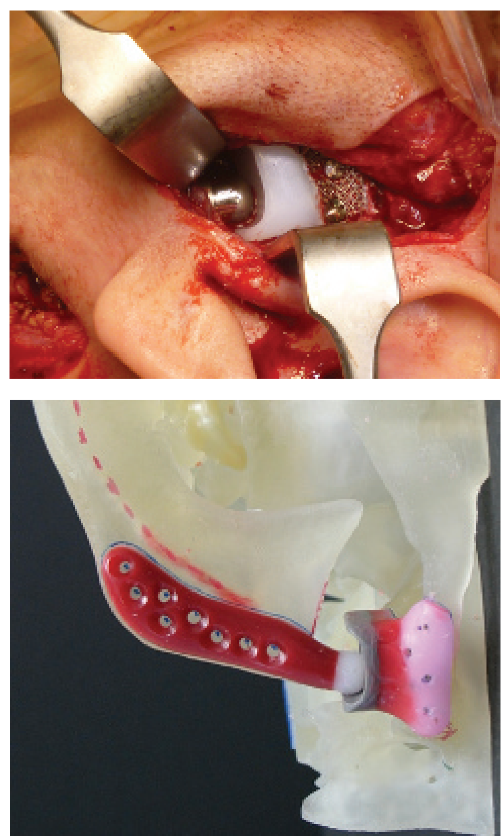

Figure 64.3 Fit of the condylar component in the fossa on the model and in situ should match.

irrigation. At least three bicortical screws should be used with the most important one being the most proximal, which is the point of maximum torque. Movement of the prosthesis should now be assured in function. If less than 30 mm movement can be achieved, either the position is incorrect or a coronoidectomy may be required. If there is dislocation then light IMF elastics will be required post-operatively for 1 week until the vertical stability is re-established. This can occur following previous coronoidectomy or with closure of anterior open bites, where the vertical pull of the temporalis has been reduced.[6] Once the occlusion is satisfactory again gown and gloves contaminated intraorally are changed. The fit and movement of the condyle within the fossa are checked and the wound is irrigated with gentamicin solution. If all is satisfactory the wounds can then be closed.

The author prefers a single 12 suction drain introduced through the upper wound extending over the prosthesis into the lower wound subperiosteally as this covers all the areas of potential wound leakage. This is secured behind the ear with black silk and is removed on the first post-operative day.

At this stage, the abdominal fat graft is placed if desired and packed around the articulating surfaces. The upper wound is closed with continuous resorbable sutures (Vicryl or PDS) to the temporalis fascia and periosteum to cover the joint but ensuring that the drain is not inadvertently held too tightly into the wound. The subcutaneous tissues are the closed with interrupted Vicryl to bring the wound edges together and the skin with 6/0 monofilament. The lower wound is closed with continuous vicryl to the parotid fascia and subcutaneous tissues. This avoids involving the branches of the facial nerve in the closure. Monofilament is used to close the skin. The masseter is not directly closed as this shortening may reduce post-operative myofascial pain due to the muscle shortening achieved.

If there has been no dislocation intraoperatively then the arch bars can be removed and the patient recovered. Antibiotics should be continued intravenously for 24 hours then for 5 days orally. The author prefers the patient to have low-dose NSAIDs for 6 weeks (if tolerated) as there is some evidence of a reduction in heterotopic bone formation in orthopaedics and this may reduce the likelihood of re-ankylosis. In any case, they provide good analgesic properties suitable to this form of surgery. Therabite passive mobilization should be commenced the first post-operative day and continue for at least 6 months along the minimum recommended protocol of seven seconds opening seven times at least seven times a day, initially aiming to improve opening by 1–2 mm per day. The opening at the start of the day will have declined compared with the night before, so the measurements should be taken at the same time every day. Most primary joint replacement patients should achieve opening of above 25 mm within 6 weeks and 30 mm by 3 months, with the pain scores diminishing rapidly towards zero. Dietary improvements take a little longer to achieve.

Post-operative stay is between 24 and 72 hours in most instances. The patients should be advised according to the American Society of Orthopaedics guidelines to have prophylactic antibiotics prior to invasive dental surgery for 2 years following prosthetic insertion. Prosthetic failure secondary to a dental and ear infection is disastrous and can be prevented by early aggressive surgical management and antibiotics. Infection in the early post-operative period secondary to dental infection can be prevented by ensuring good pre-operative dental state. Drains are removed at 24 hours and sutures are removed at 5–7 days.

All patient details should be entered into a database for long-term assessment of outcome and for comparison of outcomes of prostheses within a national/international database when available. The UK database has now been established for 5 years. The companies monitor failures as a requirement for the American FDA.

COMPLICATIONS

These may be divided into peri-operative and post-operative.

Haemorrhage

This can occur from the superficial temporal vessels, the retromandibular vein behind the ramus, the masseteric vessels deep to the sigmoid notch/ condylar periosteum, the pterygoid venous plexus or occasionally deeper vessels medial to the condyle such as the maxillary artery, the middle meningeal and even the internal jugular vein, which can be in close proximity either with a large ankylotic mass or following contracture due to previous surgeries. It is often difficult to control haemorrhage through the 1 cm × 1 cm wound following condylectomy hence the best method of control of haemorrhage is prevention by a careful technique. Blood should have been group and saved as transfusion is occasionally required. Usually the haemorrhage can be temporarily controlled by pressure. The former sites are definitively controlled in the usual manner of ligation or diathermy, paying attention to the position of the facial nerve branches. Occasionally, more proximal ligation of the external carotid or jugular may be required (Figure 64.4) and these can be accessed by a suitable extension of the retromandibular wound. Surgicel and pressure can also be used to control pterygoid oozing. Drainage of the wound will show any late re-opening of vessels due to the hypotensive anaesthesia being reversed and the blood pressure should be permitted to rise prior to wound closure.

Dislocation

Dislocation of the prosthesis is rare and usually associated with previous coronoidectomy reducing vertical stability of

Figure 64.4 Exposure and tie of the terminal external carotid artery may be required when uncontrollable haemorrhage persists.

the joint. Occasionally, closure of an open bite will cause a similar effect. If this occurs intraoperatively then the arch bars should be left in situ and 1 week light IMF elastic used to control inadvertent wide opening. By the end of 1 week sufficient vertical stability has been regained. Post-operative dislocation may also due to joint malpositioning or dystonic contractions. The patient should be returned to theatre to check the occlusion. If this is stable following relocation, which often occurs with inferiorly directed light pressure, then a means of obtaining IMF should be achieved and the patient placed in light elastics for 1 week. The wounds should only be opened as a last resort as this will markedly increase the risk of infection. If the prosthesis is malpositioned then immediate revision may be the only option.

Facial nerve injury

Facial nerve palsies are common post-operatively particularly in the temporal branch and especially following revision surgery.[7] They are usually temporary due to stretching of the tissues to gain adequate access for placement of the prosthesis. Permanent palsies can be dealt with by brow lift and other ‘cosmetic’ procedures.

Infection

Infection of any prosthesis is often staphylococcal and occasionally acinetobacter-related and appropriate prophylactic antibiotics should be used. The author recommends prophylaxis for invasive procedures causing bacteraemia similar to those for bacterial endocarditis prevention for 2 years post-operatively according to the American Association of Orthopaedic Surgeons guidelines. Infection may present with obvious signs of redness and drainage of pus from the wounds. Usually low grade infection will present as increasing restriction of opening and pain. Prosthetic removal is almost inevitable and should be followed by a period of occlusal stabilization with a gentamicin containing acrylic spacer. Biofilm formation – whereby colonies of bacteria are covered by an almost impermeable polysaccharide membrane – may present more insidiously with ongoing pain and restriction, but with no other clinical or haematological signs of infection. Antibiotics cannot penetrate the biofilm and prosthetic removal as above is indicated.

Allergy

Allergy to the prosthetic material can occur to any of the components of the prosthesis. Prevention by appropriate allergy testing pre-operatively may reduce this phenomenon although there is a suggestion that patients with failing prosthetic hip replacements develop allergy due to sensitization and lymphocyte activation. Whilst most orthopaedic patients are not tested for metal allergy, these findings cannot be confirmed, however, approximately 10% of the population are allergic to one or more component of cobalt–chromium alloy (usually nickel), whilst 20% with a functioning prosthetic hip are and 60% with a failing prosthesis are. Other factors may be involved, however, where allergy is suspected the ongoing swelling may lead to traction facial nerve palsy and the prosthesis requires removal and ultimate revision to an all titanium prosthesis (Figure 64.5).

Myofascial pain

This is most common in patients who started with marked restriction of mouth opening and tends to start around 6 weeks when post-operative mouth opening tends to exceed the pre-operative level. Some surgeons commence low-dose tricyclic medication immediately post-operatively whilst others will commence this when myofascial pain develops. In any case, it can usually be discontinued at 1 year when the mouth opening has reached a maximum and has been stable for several months. Botulinum injections provide an alternative for those

Figure 64.5 Traction palsy of facial nerve due to swelling consequent upon chromium allergy. This resolved following replacement of the prosthesis with all titanium.

unable to tolerate the occasional sedative side effects of low-dose tricyclics.

Long-term complications are rare and the majority of patients gain significant improvements within 1 year in pain scores (90%), dietary scores (90%) and mouth opening which persist for more than 10 years.

SUMMARY

Prosthetic replacement has a growing place in the management of end stage disorders of the TMJ, but should be confined at present to a few high-volume operators to adequately assess outcomes. The introduction of NICE guidelines and a National Database permits medium- and long-term assessment.

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Top tips

- Consider pre-operative vascular imaging in patients with extensive ankylosis or several previous procedures as the vessels can lie in the ankylotic mass.
- Access to the carotid can be achieved by deepening the retromandibular wound onto digastric and anterior to the sternocleidomastoid muscles.
- Always group and save these patients as blood loss can be sudden and catastrophic.
- Assess all patients for metal allergy if an alloplastic prosthesis is to be used and use an all titanium prosthesis if allergy exists.
- Rapid access to the joint is facilitated by the pretemporal fascial dissection approach.
- Always check for dislocation of the prosthesis intraoperatively and place in light elastic traction for one week if this can be achieved.
- If inadequate opening is achieved intraoperatively consider coronoidectomy.
- Ensure adequate mobilization post-operatively by regular use of the Therabite device.

SECTION IX

CLEFT LIP AND PALATE

65

Primary closure of the unilateral cleft lip

SERRYTH COLBERT AND DAVID DRAKE

CONTENTS

INTRODUCTION

Clefts of the lip and/or palate (CLP) are the most common craniofacial birth anomalies and are among the most common of all birth anomalies, with birth prevalence ranging from 1 in 500 to 1 in 2000 depending on the population. Successful management of patients born with cleft lip and/or palate requires multidisciplinary, highly specialized team management from birth to adulthood. The technique of repairing a unilateral cleft lips is outlined.

OBJECTIVES OF CLEFT LIP REPAIR

The essential objectives of cleft lip repair are the restoration of normal function and appearance of the lip and nose. This is achieved by re-establishing normal insertions of all the nasolabial muscles and correct anatomical position of the other soft tissues, including the mucocutaneous elements. Therefore, an anatomic and functional balance between the soft tissues and the skeleton is re-established.

1. *Skin*: The skin is corrected in both vertical and horizontal orientation. To restore normal height of both sides of the cleft relative to the non-cleft side, it is necessary to restore the normal length of the skin on the cleft side using various techniques, such as the rotation advancement design (Delaire and Millard), undulating wavy flaps (Pfeiffer), straight-line design (Rose–Thompson), lower lip Z-plasties/triangular flaps (Tennison–Randall, Skoog, Trauner, or Malek), the quadrangular flap (Le Mesurier), or a combination of the advancement rotation and wavy-line techniques (Afroze). The skin of the lip on the medial element is short as a consequence of the change in normal muscular actions. Careful reconstruction of the nasolabial muscles allows the overlying skin to lengthen to the correct lip height.
2. *Muscle*: The fundamental goal of surgery is to achieve anatomic muscular reconstruction, particularly with respect to anchorage of the complex nasolabial muscles of the cleft side to the nasal septum and muscles on the non-cleft side (Figure 65.1). It is necessary to reconstruct the nasolabial muscles of the cleft such that the skin margins are not under tension at the moment of skin closure (Figures 65.2 and 65.3). If the primary nasolabial muscle reconstruction is good, anatomy, function, skeletal growth, and total facial aesthetics can be excellent.
3. *Nose*: The nasal septum is deviated in unilateral cleft lip. There are two reasons:
   - Position of the anterior nasal spine (ANS) – it is positioned towards the non-cleft side and therefore pulls the septum which is attached to it towards the non-cleft side.
   - Muscle attachments of the medial side – the most nasal and deep bundles of orbicularis muscle insert into the mucoperichondrium and anterior nasal septum and therefore they pull the caudal part of the septum towards the medial side.

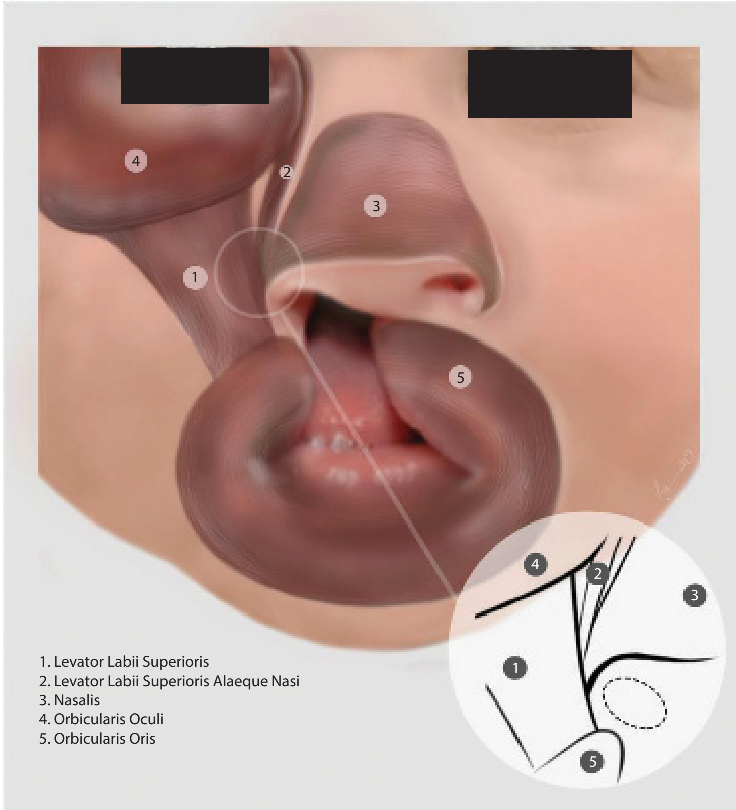

Figure 65.1 Muscle anatomy in unilateral cleft lip.

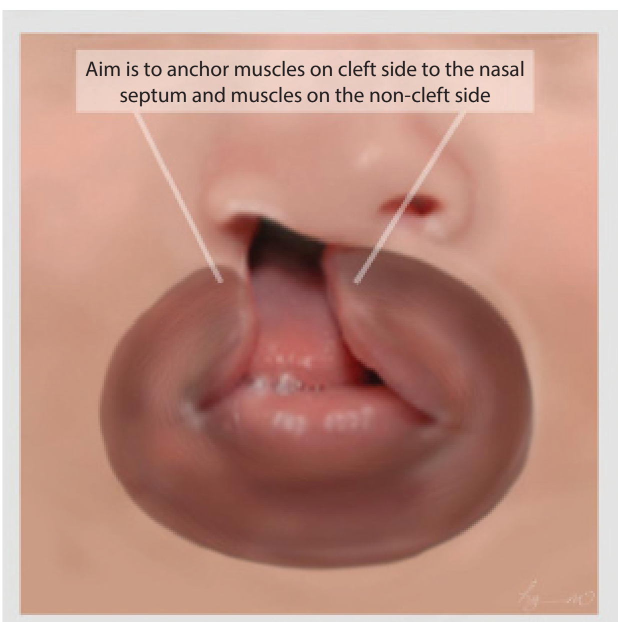

Figure 65.2 Functional muscle reconstruction in unilateral cleft lip.

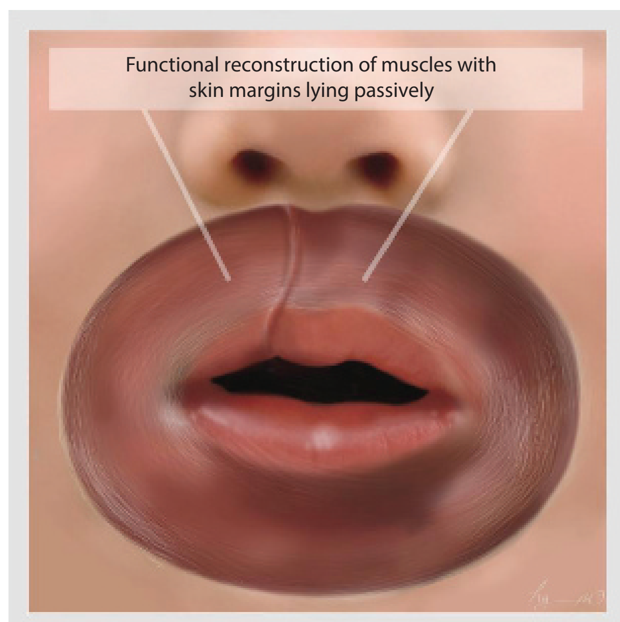

Figure 65.3 Muscle in repaired unilateral cleft lip.

Septal deviation causes the upper lateral cartilage to buckle depressing the radix, and also causes the lower lateral cartilagenous framework to shift and thereby collapsing the dome on the lateral side (Figure 65.4).

Septoplasty at the time of lip repair produces a straighter nasal septum positioned in the facial midline and restores the patency and natural width of the nostril (Figure 65.5). To achieve the proper midline

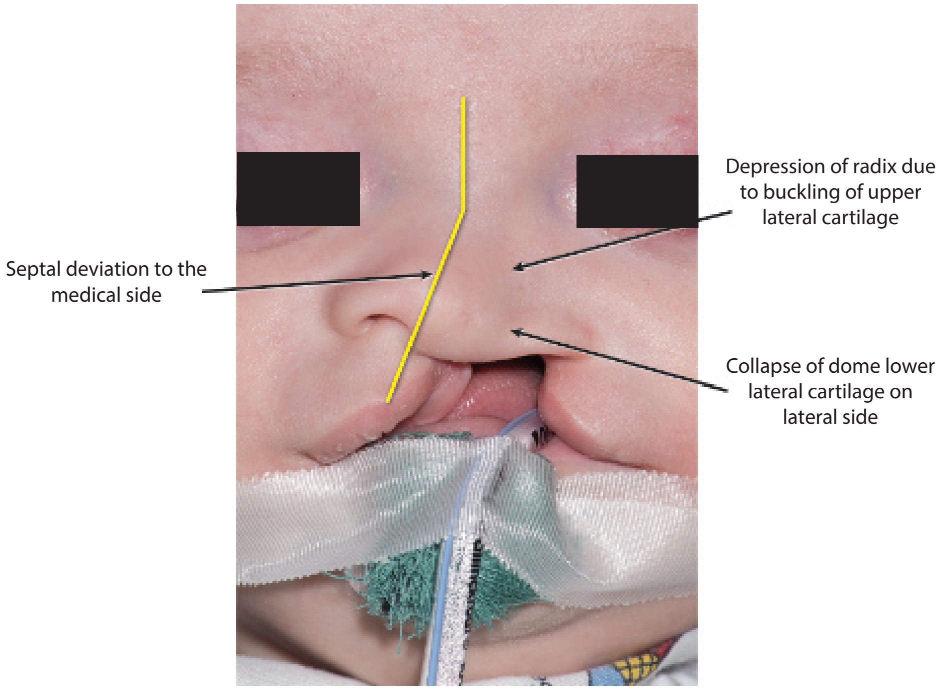

Figure 65.4 Deviation of nasal septum to non-cleft side.

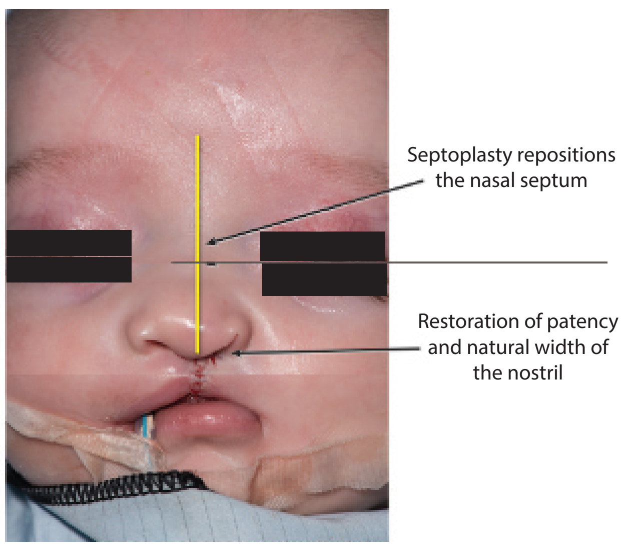

Figure 65.5 Septoplasty with repositioning of the caudal aspect of the nasal septum.

position and attitude of the nasal septum, the surgeon must perform a wide subperichondrial dissection on both sides of the septum. Once the deviated nasal septum is repositioned, nostril patency is re-established on the cleft side.

The nasal floor is also reconstructed to eliminate the vestibular oral nasal communication if the palate is involved. A vomer flap is used when possible to repair the anterior hard palate in continuity with the floor of nose. There is no evidence to support the hypothesis that vomer flaps restrict maxillary growth.

4. *Alveolar cleft segments*: The distance between the greater and lesser segments is proportional to the width of the cleft lip. The segments will be approximated from pressure exerted on them by the repaired cleft lip moulding the anterior element of the greater segment.
5. *Anterior hard palate*: A vomer flap is raised and inset into the cleft margin (Figure 65.6) to close the anterior hard palate at the time of repair of the cleft lip to establish continuity of nasal floor closure (Figure 65.7). There may be some narrowing of the width of the posterior cleft palate following vomer flap closure.

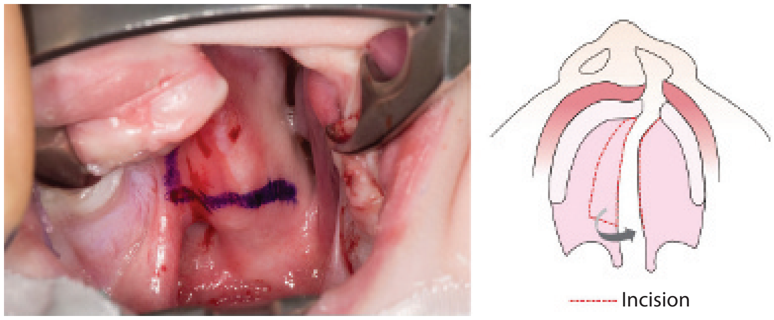

Figure 65.6 Raising a vomer flap into the anterior hard palate.

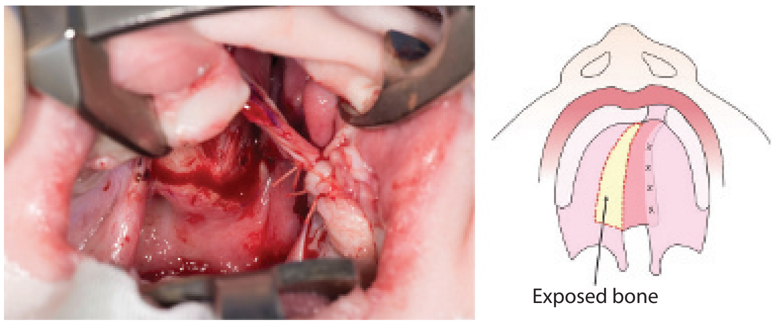

Figure 65.7 Insetting a vomer flap into the anterior hard palate.

THE SOUTH WALES CLEFT TEAM TECHNIQUE FOR CLEFT LIP REPAIR – ADVANCEMENT/ROTATION LIP REPAIR WITH AN INFERIOR TRIANGULAR FLAP

The authors close the cleft lip at 3 months of age and the repair involves the following key steps:

1. An advancement/rotation repair of the cleft lip incorporating an inferior triangular flap addressing the medial shortening and lateral displacement while restoring normal anatomy, lip length and symmetry.
2. Achieving a functional muscular repair by restoring the displaced muscles to their correct anatomical position and recreating the muscular rings of mid and lower face.

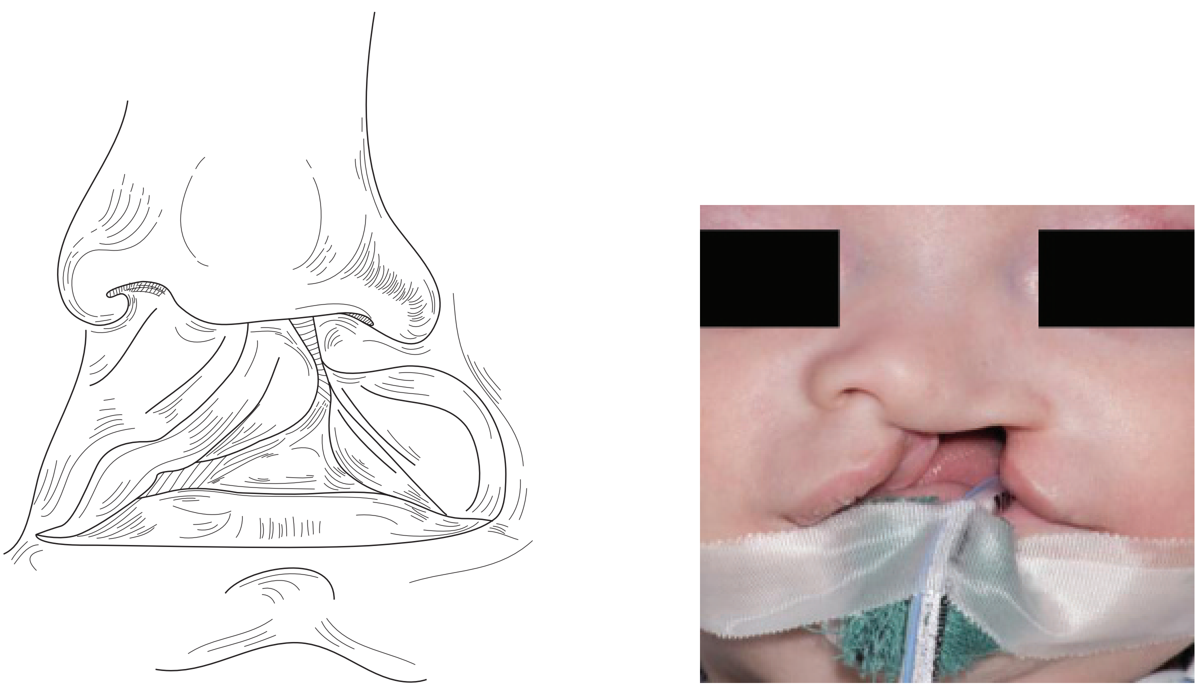

Figure 65.8 Left unilateral cleft lip.

3. Using a vomer flap to repair the anterior hard palate in continuity with the repair of the floor of nose.
4. Performing a McCoomb's nasal dissection if required to release the lower lateral cartilage allowing it to sit in a correct anatomical position.
5. Straightening of the caudal aspect of the nasal septum to place the septum in its correct central anatomical position.

The key surgical steps in the authors' surgical protocol are as follows:

1. *Left complete cleft lip*: Identification of key surgical landmarks, show both on an illustration and clinical photograph (Figure 65.8).
2. *Skin markings*: The skin markings include the following key landmarks (Figure 65.9):
   - *Cupid's Bow markings*: Non–cleft-side peak, trough and peak on the cleft side (a point on the cleft side equidistant from the trough of the cupid's bow)
   - *First change in the appearance of the white roll on the lateral element*: The point of first change of the white roll and where the white roll and vermilion start to converge
   - *Base of columella*: Remember it is rotated
   - *Alar Base*: The inferior lateral point
3. *Medial element incision*: Curved incision along the short medial element (Figure 65.10). The aim is to place the scar in the line of the natural philtral ridge. The medial side of the philtrum must be lengthened to match the non-cleft length. The incision does not extend along the base of columella at its superior aspect. The incision extends from the base of columella on the cleft side to the cleft side peak of the cupid's bow curving parallel to and just above the white line. It is curved medially and turns across the vermilion through 90° at the cupid's bow peak and extends just past the wet–dry mucosal junction.

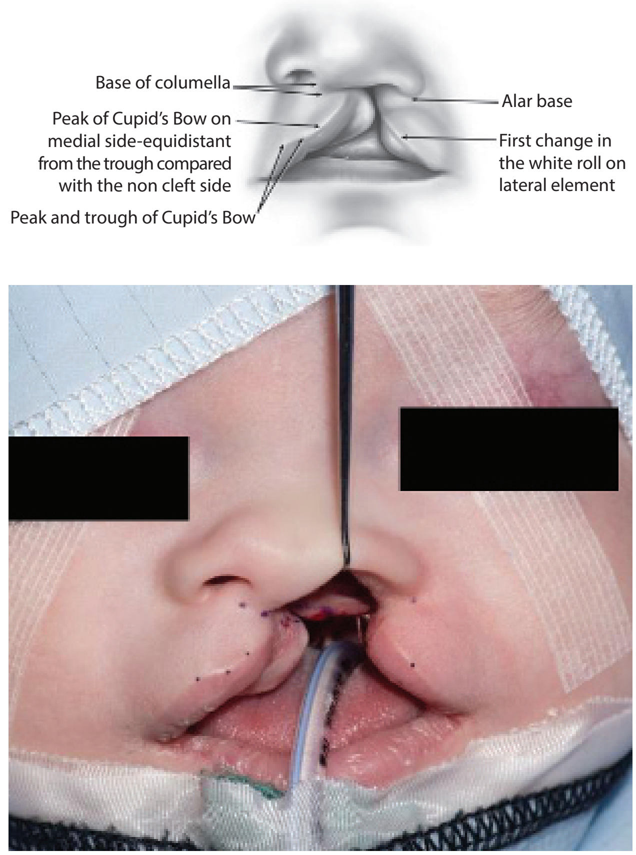

Figure 65.9 Skin markings on complete left unilateral cleft lip.

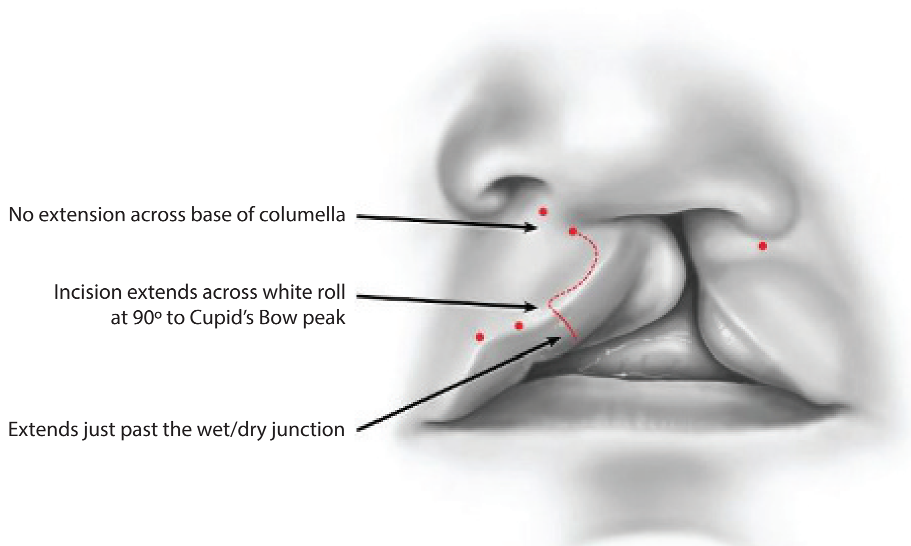

Figure 65.10 Curved incision on medial element.

4. *Lateral element incision*: The incision on the lateral side extends from the alar base along the junction of the nasal and lip skin to meet the mucosa at 90° (Figure 65.11). The incision then extends from this point along the white roll parallel to the skin/mucosal junction to meet the upper point of the lateral triangular flap.
5. *Inferior triangle incision*: An inferior triangular flap is incorporated along the incision in the lateral element and is inset into a backcut in the medial element to lengthen the deficient medial element (Figure 65.12). The triangle and the backcut must be the same height above the white roll. The addition of an inferior triangle to the advancement/rotation repair of a cleft lip allows full restoration of length without the overextension of the medial incision under the base of the collumella. The lip length must not be shorter than the normal side at end of the surgery.
6. *Advancement/rotation*: Advancement of the lateral side to align with the rotated short medial element (Figure 65.13).
7. *Intranasal incision*: The intra-nasal incisions are illustrated in Figure 65.14.
   - The incision on the medial element extends at a tangent to the curved incision extending into the floor of the nose along the nasal/oral mucosal junction. It

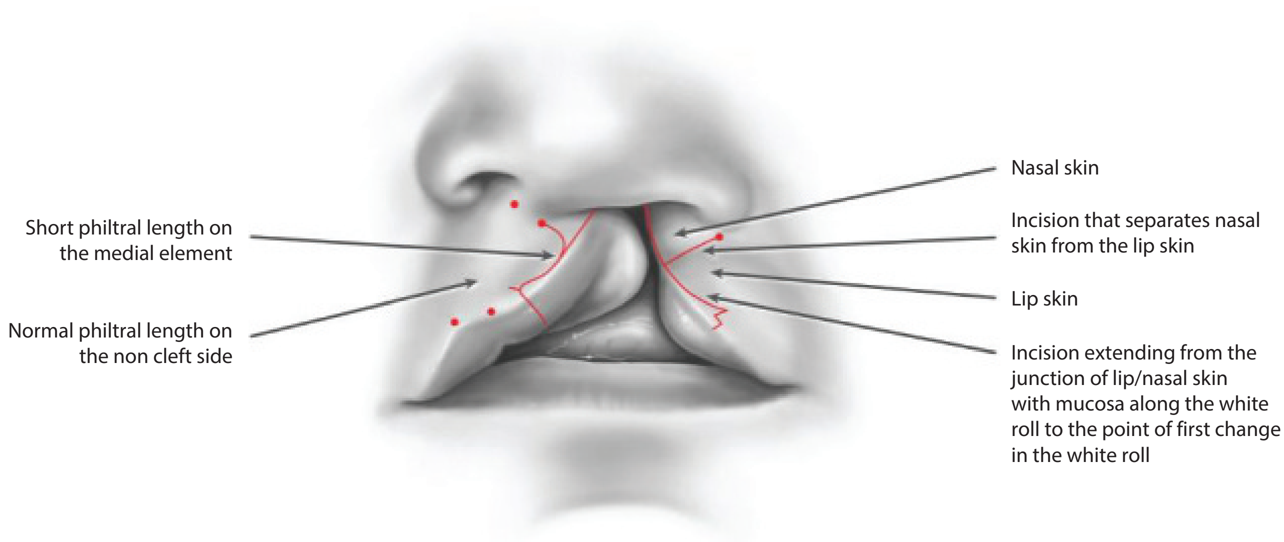

Figure 65.11 Lateral skin incision.

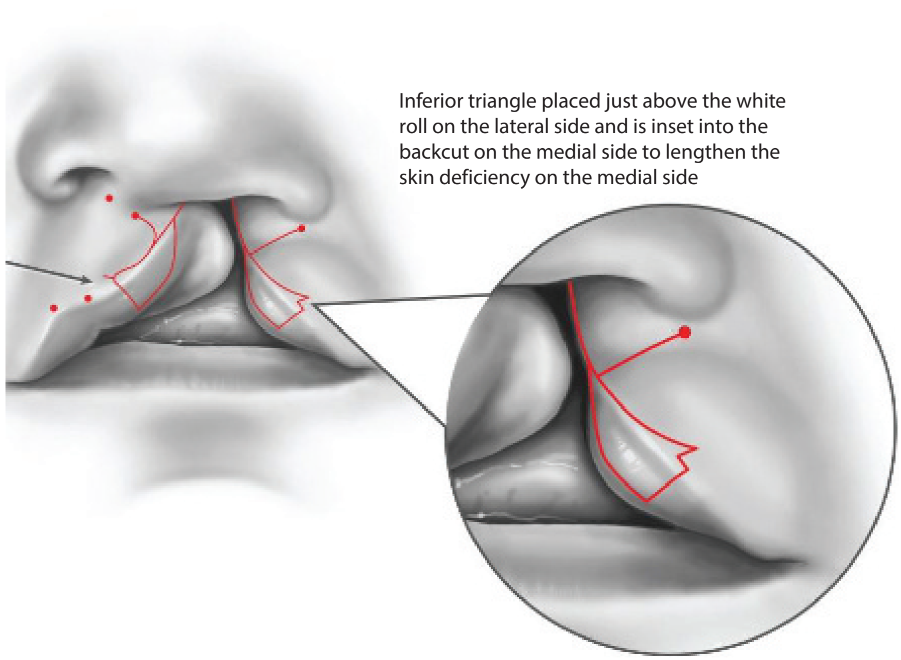

Figure 65.12 Inferior triangle and backcut.

will connect to the vomer flap and the flap raised will form the medial floor of the nose.

- The incision on the lateral element is a continuation of the lateral element incision into the nose parallel to the junction of the skin-mucosal junction. This incision extends to the alveolus and sits just below the inferior turbinate.

8. *Sterile mucosa incision*: Outline of sterile mucosa

- The incisions are extended across the white roll medially and laterally at 90° to the white roll. They extend through the wet–dry junction and then up into the nose. The mucosa outlined is the sterile mucosa.

9. *Advancement/rotation*: Advancement rotation skin markings with an inferior triangle (Figure 65.15). The Vermilion border is tattooed with ink – these points act as landmarks to allow accurate reconstruction of the white roll. Local anaesthetic is infiltrated and the marking incised. The sterile mucosa is excised and the muscle edges are identified along both sides of the cleft margin.
10. *Muscle dissection*: The muscle is dissected on both sides of the cleft to separate the muscle from the mucosa and dermal layers.

- On the medial side, dissection of the muscle is carried out to relieve the abnormal attachments from

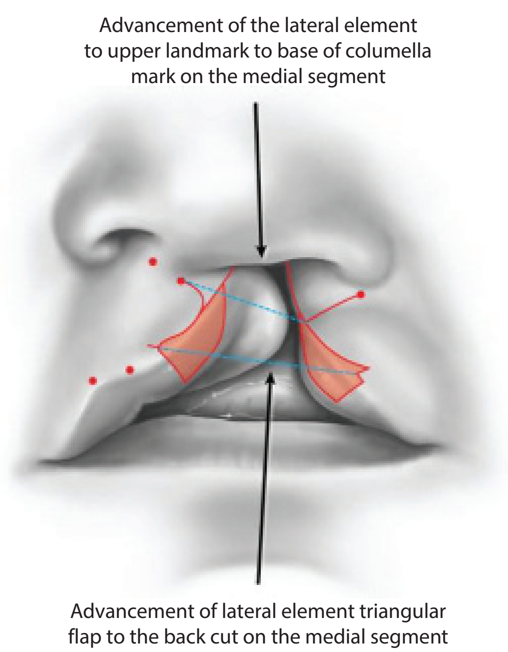

Figure 65.13 Advancement and rotation.

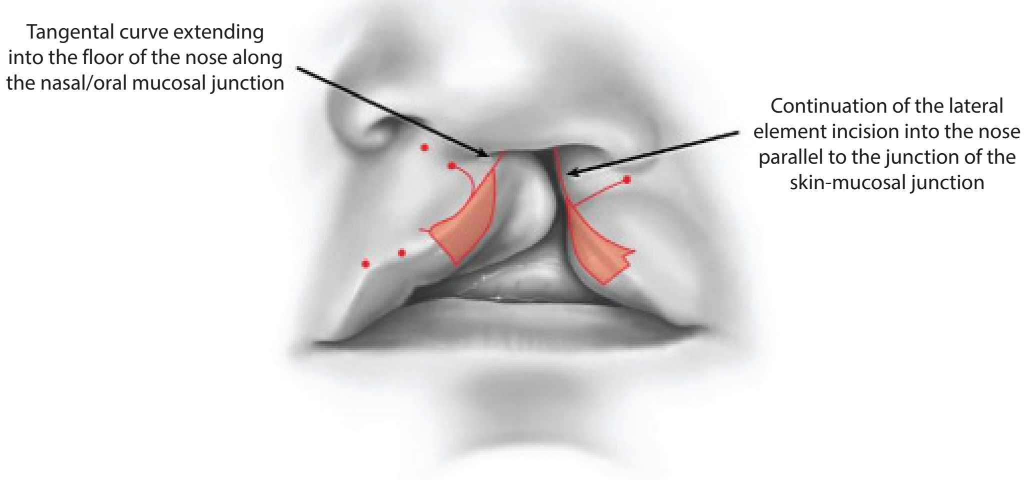

Figure 65.14 Nasal incisions.

the ANS and the columella allowing lengthening and rotation of the skin deficiency on the medial element (Figure 65.16).
- On the lateral side, muscle dissection is done to identify and mobilize the head of the transverse nasalis and the length of orbicularis (Figure 65.17).

11. *Subperiosteal dissection*: This is peformed if the transverse nasalis muscle will not reach the ANS. After the muscle dissection is completed, an incision is made in the buccal sulcus up to the nasal margin of the cleft. A wide subperiosteal dissection is made from the vestibule on the cleft side over the piriform rim, nasal bone, infraorbital and malar regions to lift the facial mask taking care to protect the infraorbital nerve (Figure 65.18).
12. *McCoomb nasal dissection*: As required if the lower lateral cartilage will not sit in the correct position when the nasal muscle is approximated. Access is gained to the lower lateral cartilages through a medial approach allowing blunt dissection of the cartilage from the overlying skin/nasal mucosa. The plain of dissection is subdermal and submucosal. The lower lateral cartilage can also be approached from the lateral aspect if required, but this is not commonly performed (Figure 65.19).The McCoomb's dissection reduces the buckling effect of the lateral crus of the lower lateral cartilage allowing it to sit in a more natural position.
13. *Septoplasty*: Correction of the caudal aspect to the deviated nasal septum provides stability and exact positioning of the previously lifted alar crus of the cleft side and nasal tip. This allows the nose to grow in a balanced way with equal muscular force being exerted on both sides. The caudal aspect of the nasal

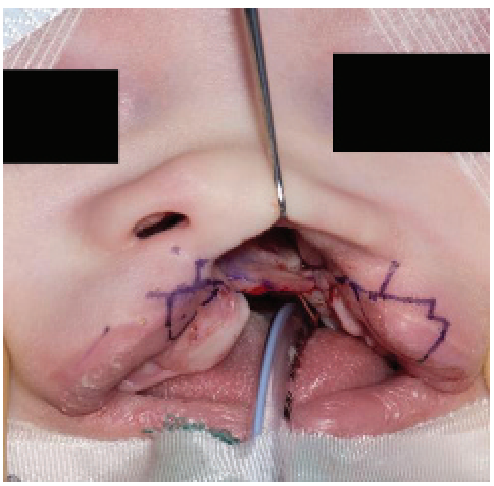

Figure 65.15 Sterile mucosa on medial and lateral elements.

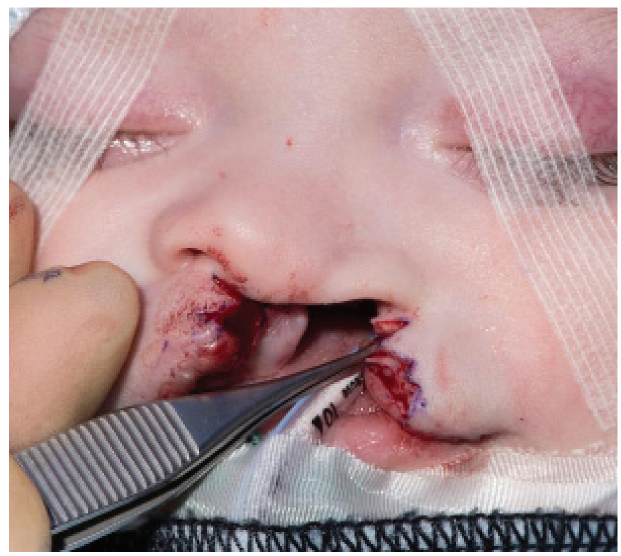

Figure 65.17 Dissection of muscle on the lateral side.

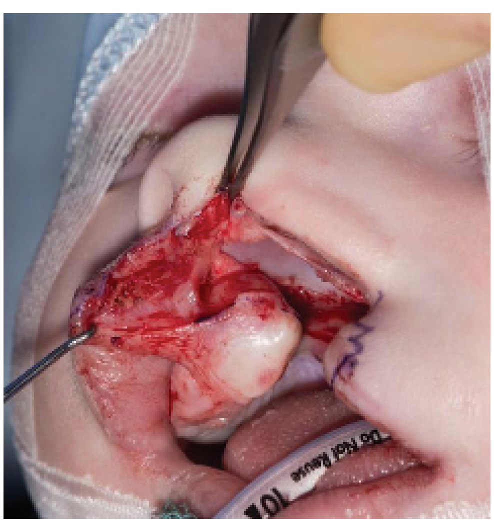

Figure 65.16 Dissection of muscle on the medial side.

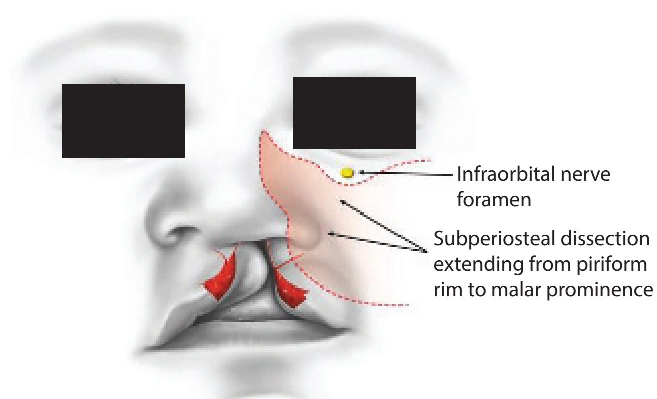

Figure 65.18 Subperiosteal dissection on lateral side.

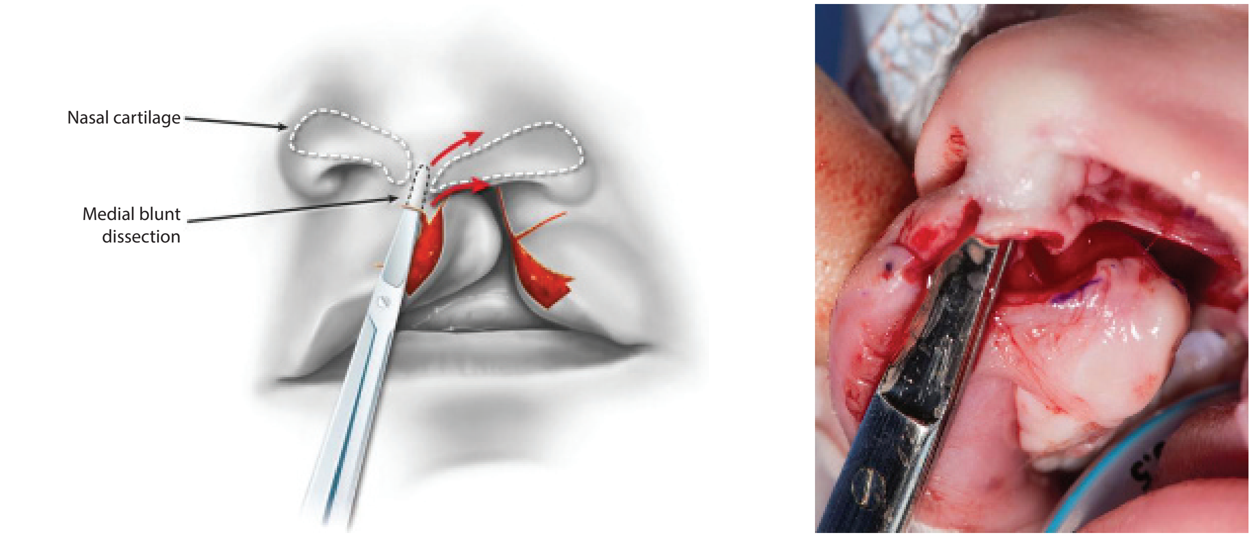

Figure 65.19 McCoomb nasal dissection.

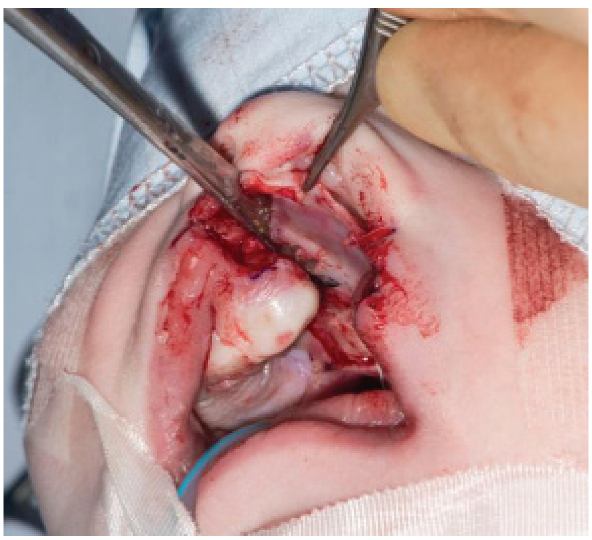

Figure 65.20 Exposure of the deviated caudal aspect of the nasal septum.

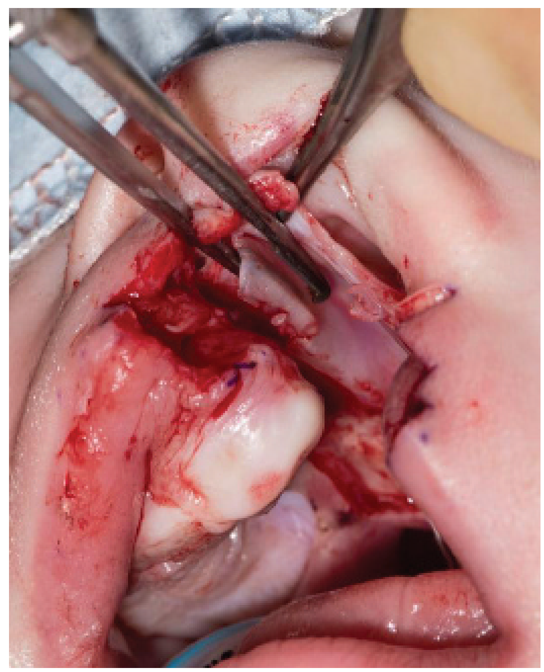

Figure 65.21 Detachment and straightening of caudal aspect of nasal septum.

septum is then carefully isolated and freed through the same cleft incision by splitting and raising the perichondrium on both sides (Figure 65.20).

- The septum is detached from its attachment to the nasal spine and maxillary crest, straightened and repositioned centrally (Figure 65.21).

14. *Nasal floor reconstruction*: The nasal floor is reconstructed by suturing the hair-bearing nasal mucosa on both sides, posteriorly closing the lateral nasal floor to the vomer flap (Figure 65.22).
15. *Suturing of transverse nasalis to ANS/septum*: This is to secure the position of the base of the septum (Figure 65.23).
16. *Natural approximation of orbicularis oris*:
    - The orbicularis is approximated and sutured to a natural position maintaining the muscle length (Figure 65.24).
17. *Skin closure*:
    - Tension free skin closure is performed (Figure 65.25). This is made possible by the subperiosteal dissection, radical mobilization and suturing of the transverse nasalis and orbicularis muscles.

Figure 65.22 Reconstruction of nasal floor.

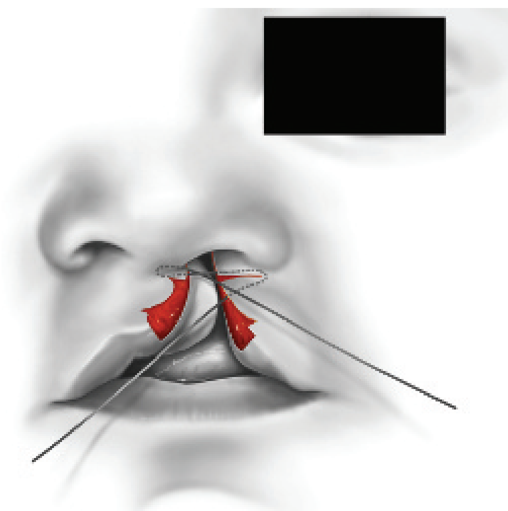

Figure 65.23 Suturing of transverse nasalis to anterior nasal spine (ANS)/septum.

Figure 65.24 Functional repair of orbicularis oris.

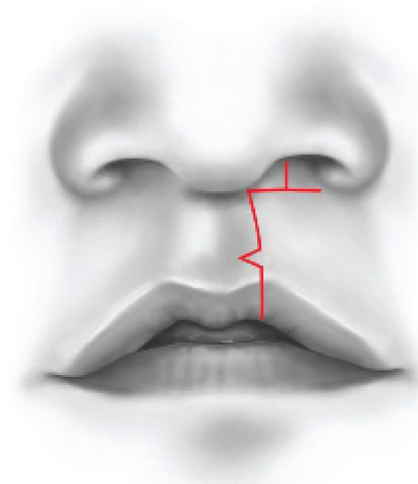

Figure 65.25 Tension free closure of skin.

COMMON TECHNIQUES OF CLEFT LIP REPAIR

Millard cleft lip repair

FLAP DESIGN

The Millard repair is based on a rotation flap on the medial cleft side coupled with an advancement flap on the cleft lateral side. The incision then bowed in a curvilinear fashion near the base of the columella crossing the philtrum towards the far lateral extent of the columellar base (Figure 65.26). In one form or another, it is the most widely practiced method today.

The rotation advancement technique relies on a 'cut as you go' strategy that allows continuous modifications during the design and execution of the repair. It does not adhere to strict geometrical principles or measurements.

However, it may leave a scar crossing the midline at the base of the columella and cause shortening of the lip on the cleft side with resultant vermilion notching and whistle deformity.

Delaire cleft lip repair

Delaire's cleft lip technique incorporates a curvilinear incision that extends up and parallels the medial cleft margin but stops near the medial edge of the base of the columella. The lateral lip element advancement incision curves outward and then medially as it extends superiorly before it again extends to the alar base (Figure 65.27).

Delaire does not incorporate an inferior triangle into his cleft lip repair, which limits the extra length that can be gained. A Delaire repair does not include a vomer flap.

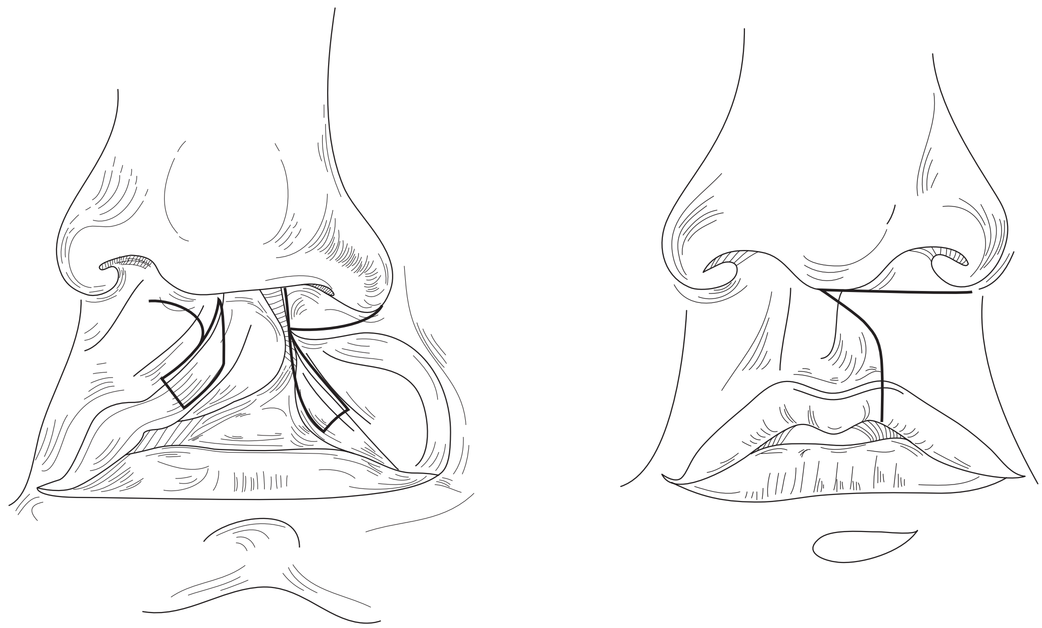

Figure 65.26 Millard repair.

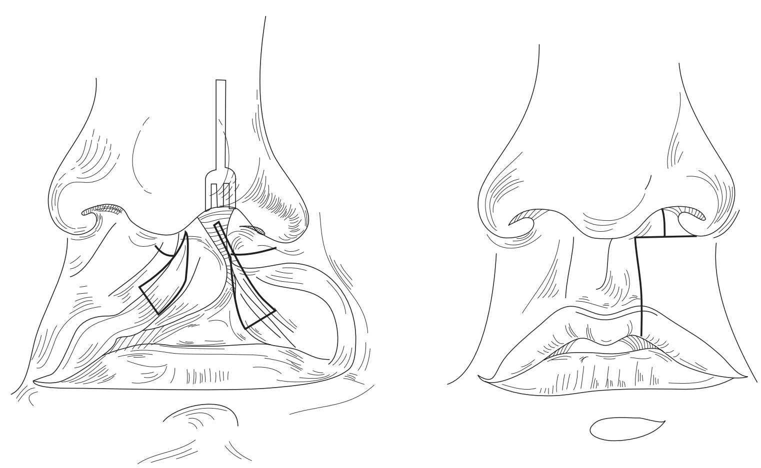

Figure 65.27 Delaire repair.

Pfeiffer cleft lip repair

FLAP DESIGN

Pfeifer described a wavy-line repair that allowed downward rotation as the curves were approximated into a straight line. The two curves are brought together such that the highest and lowest points of one curve are approximated with the corresponding highest and lowest points of the other, thus creating a straight line (Figure 65.28).

The Pfeiffer repair achieves good vertical length soft-tissue reconstruction, but in some cases this can be at the expense of soft-tissue reconstruction in the horizontal dimension.

Afroze cleft lip repair

FLAP DESIGN

The Afroze incision is a combination of two incisions – the Millard incision on the medial cleft side and the Pfeiffer incision on the cleft side (Figure 65.29). The flap is designed so that the Millard flap on the cleft side rotates downwards and the peak of the distal curve on the Pfeiffer flap is positioned in the triangular defect formed by the downward movement of the Millard flap.

The lip scar does not lie along the philtrum – this is the only disadvantage of this technique. However, the scar heals exceptionally well as the wound is closed under no tension whatsoever.

Tennison cleft lip repair

FLAP DESIGN

The triangular flap repair was initially described in 1952 by Tennison. Tennison's technique made use of an inferior backcut that begins not far above the cleft-side peak of the Cupid's bow of the medial lip element and angled superolaterally. Precisely measured triangle flaps allow vertical lengthening of the medial lip element while enabling lengthening of what is often an otherwise short transverse lateral lip element without compromising the ideal basal position of the philtral column incision (Figure 65.30).

The main disadvantage of the triangular flap repair technique is that the philtrum on the cleft side is violated

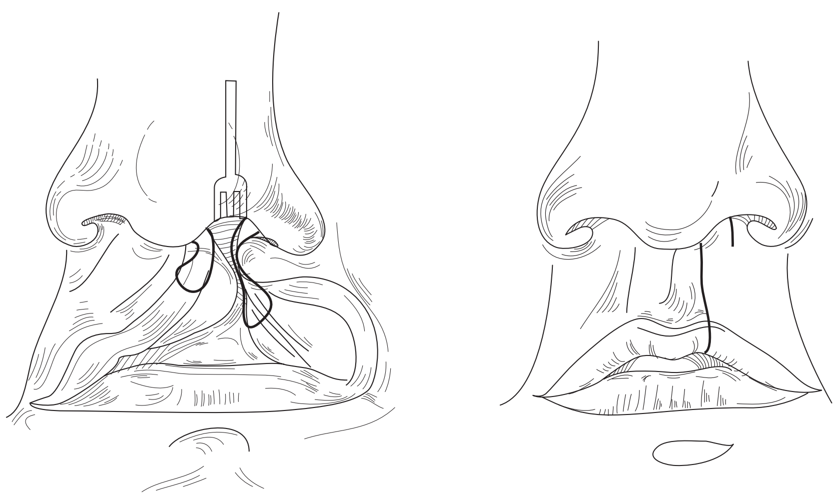

Figure 65.28 Pfeiffer repair.

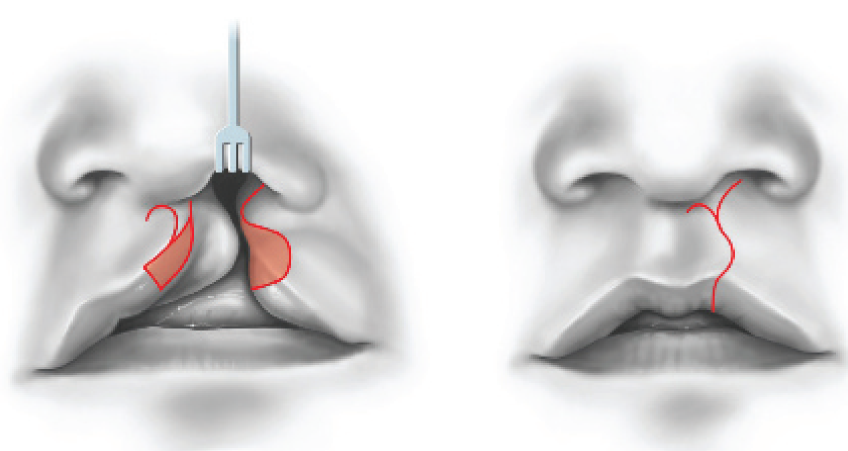

Figure 65.29 Afroze repair.

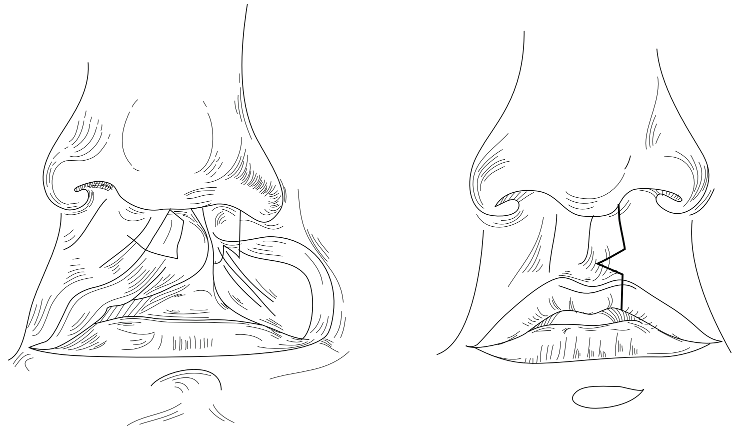

Figure 65.30 Tennison repair.

by the triangular flap. Some authors believe this leaves a more noticeable scar. Another potential disadvantage is the difficulty in modifying the repair or performing secondary revision at a later stage due to the zigzag scars.

Fisher cleft lip repair

FLAP DESIGN

The repair allows for a repair line that ascends the lip at the seams of anatomical subunits. Applying the principle of anatomic subunits to cleft lip repair, the 'ideal line of repair' should be one that ascends the lip from the cleft-side peak of Cupid's bow to the base of the nose along a line exactly mirroring the non-cleft-side philtral column (Figure 65.31). These manoeuvres help to preserve natural subunit boundaries allowing for rotation and medial lip lengthening at the expense of narrowing the philtrum to a degree.

Fisher often adds a small inferior triangle just above the cutaneous roll for additional rotation and feels that this accentuates the pout of the lip. While this technique is included in the category of rotation/advancement repairs, it is clearly a hybrid of multiple principles, including triangle-flap techniques and use of geometric and curvilinear incisions to approach a vertically oriented closure.

Repair of the incomplete cleft lip

The repair of the incomplete cleft lip follows the same principles as outlined for the repair of the complete cleft lip. The incision is modified to divide the nasal skin from the lip skin in a line along the base of the nasal sill (Figures 65.32 and 65.33). The texture of the nasal skin is different to the texture of the skin of the lip and the incision line is placed between the junction of both skin types. The texture of the skin that is excised is abnormal due to the lack of underlying muscle insertion. A small wedge excision into the nasal sill may be used to prevent a prominence of scar tissue from developing in this area. The authors do not include this extension into the nasal sill as it may lead to nostril narrowing and flattening of the nasal sill. If a tissue prominence should develop, it can be easily treated with a wedge excision at a later date.

The post-operative result for an incomplete cleft lip repair is illustrated in Figure 65.34.

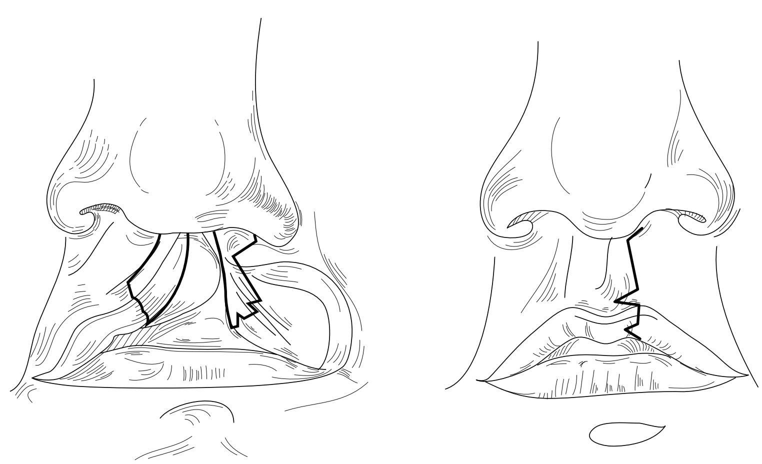

Figure 65.31 Fisher repair.

Figure 65.32 An incomplete left side cleft lip.

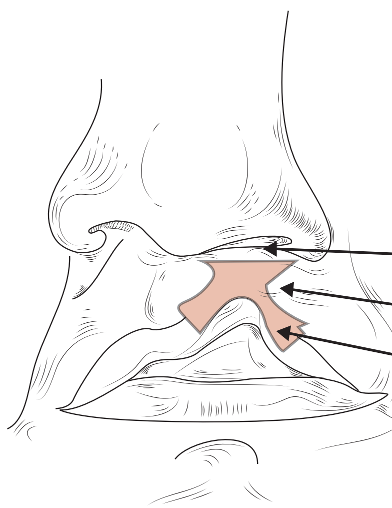

Figure 65.33 Pre-operative skin markings for an incomplete left side cleft lip repair.

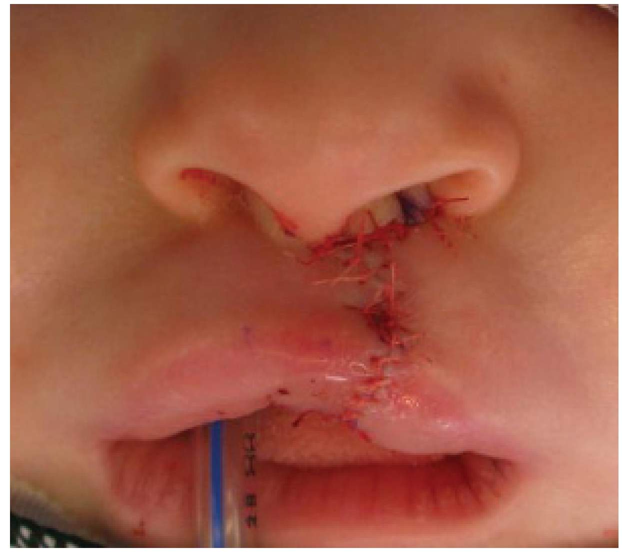

Figure 65.34 Post-operative result for the repair of an incomplete left side cleft lip.

ACKNOWLEDGEMENT

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Top tips

Careful identification of anatomical landmarks and respect for anatomical boundaries between the nose and lip.

- Wide subperiosteal undermining of the anterior maxilla.
- Identification of the anterior border of the septum, subperichondrial undermining of the nasal septum and release of ala cartilage from the vestibular skin.
- Identification and dissection of the nasalis and orbicularis muscle.
- Reconstruction of the upper and middle muscle rings with fixation of the nasalis muscle to the periosteum, just below the ANS, and fixation of the oblique part of orbicularis to the ANS and septum.
- Correct alignment of the ala base, anterior septum and columella.
- Careful reconstruction of the horizontal fibres of orbicularis.

66

Primary closure of bilateral cleft lip

KRISHNA SHAMA RAO

CONTENTS

ANATOMY

- The prolabium located centrally is devoid of muscle and consists of skin, vermillion and oral mucosa.
- There is no definitive line of demarcation between the columella and prolabium.
- The premaxilla, containing the tooth buds for future permanent incisors, may be situated centrally or asymmetrically to the right or left, anteriorly, superiorly or inferiorly or a combination thereof.
- Sometimes permanent lateral incisors are missing/hypoplastic.
- On the lateral segments, the lip vermillion is turned upwards to join the alar base. This is because both the extrinsic muscle (levator alaeque nasi, levator labii superioris, nasalis), as well as the intrinsic upper lip muscles (orbicularis marginalis and peripheralis) are oriented upwards and inserted into the alar base and maxilla along the pyriform ring (Figure 66.1).
- The lower lateral cartilages are pulled laterally, resulting in a flattened appearance of the nose.
- The septum and premaxilla are attached to the vomer as a thin stalk.

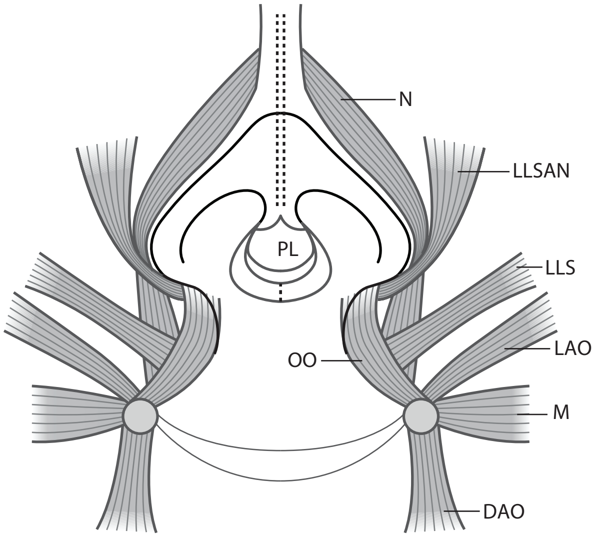
CLINICAL EVALUATION/RECORD KEEPING

- Photographs, both extra- and intra-oral
- Study models
- Orthopantomogram after 5 years of age
- Check premaxilla for mobility and fracture

TIMING OF SURGERY

- The ideal age for lip repair is 3 months.
- In less-informed societies, patients may present at any age.
- Protocols for primary repair of bilateral cleft lip presenting at any age is as follows:
  - 3 months to 2 years: lip repair
  - 2–7 years: palatoplasty first and then lip repair
  - 7 years to adulthood: palatoplasty first and then lip repair with alveolar bone grafting

When the patient presents for surgery after the age of 7 years, the premaxilla may be severely displaced and may occasionally require surgical repositioning.



PL – prolabium. N – nasalis.
LLSAN – levator labi superiosis aleque nasi.
LLS – levator labi superiosis. LAO – levator anguli oris.
M – modiolus. DAO – depressor anguli oris. OO – orbicularis oris

Figure 66.1 Anatomy.

HOW TO HANDLE THE PREMAXILLA

- In minimally displaced premaxilla in the newborn or when the child presents early (at less than 3 months of age), strapping of prolabium with dynaplast or elastics is helpful.
- In the more displaced premaxilla, nasoalveolar moulding with specially developed plates with nasal prongs to guide premaxillla and lateral segments into position can be fitted. It requires repeated visits to the clinic to adjust the plates (Figures 66.2 through 66.4).

Lip adhesion

This is a surgical procedure which allows mobilization of the nasal layer and closure of the lateral segment margins with the prolabium without mobilization and anastomosis of the orbicularis oris muscle. This allows repositioning of the premaxilla and definitive repair at the second stage some 3 months after the lip adhesion (Figure 66.4).

Premaxillary osteotomy

INDICATION

Premaxillary osteotomy is indicated in the following conditions:

- Patient aged about 7 years
- Premaxilla more than 1 cm protruded and/or deviated
- When other conservative techniques are not appropriate

Primary premaxillary osteotomy is performed using longitudinal mucosal incision, use of cutting instruments to perform a predetermined oblique ostectomy, separation

(a)

(b)

Figure 66.2 (a) Premaxilla at the tip of the nose, absence of columella and deficient prolabial tissue; (b) protruded premaxilla and deviated nasal septum.

Figure 66.3 Appliance during first stage of alveolar moulding.

(a)

(b)

(c)

Figure 66.4 Treatment progression using an appliance and strapping to guide the premaxilla.

of the nasal septum from the vomer and retropositioning the premaxilla and stabilization with resorbable bone plates. After 3 months, primary repair of lip can be undertaken (Figure 66.5).

Pre-operative assessment is shown in Figures 66.6 and 66.7.

DEFINITIVE PRIMARY REPAIR OF BILATERAL CLEFT LIP

Anaesthesia

Patients are given general anaesthesia, using an oral endotracheal, reinforced tube.

POSITION

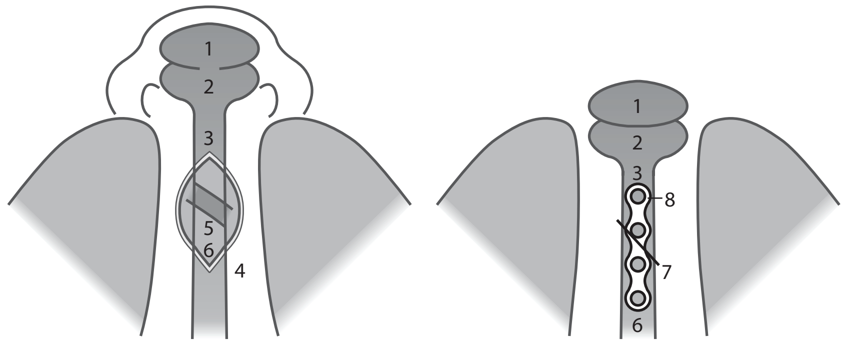
Patients are positioned with the neck extended and a mouth gag applied.

PROCEDURE

After the mouth gag is applied, marginal incisions are made along the medial aspects of the palatal shelves up to the end of the hard palate. On the premaxilla, a Y-shaped incision is made with the two short limbs encircling the premaxilla and the long limb along the vomerine mucoperiosteum. The nasal layers are elevated using Mitchell's trimmer or a plastic instrument. A single layer mucosal closure of the nasal lining is achieved from the lip to the hard palate using interrupted resorbable Vicryl 4/0 sutures with the knots inverted into the nasal cavity. The mouth gag and neck extension are then removed.

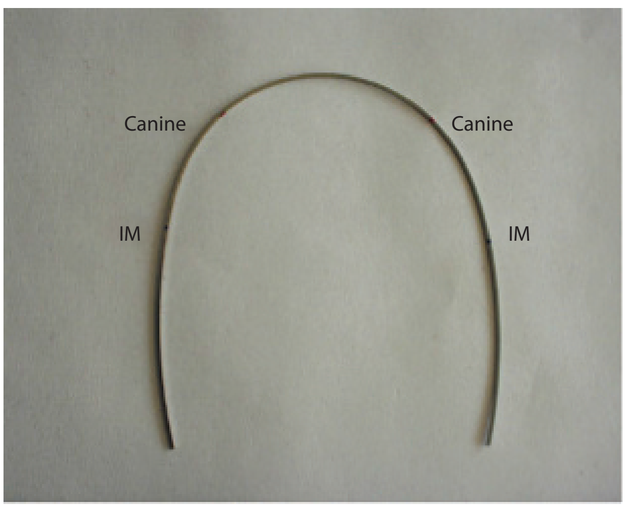
Next, lip marking should be planned, the key points to mark on the prolabium being: the apparent junction between columella and prolabium. Mark A1 and A2 at the corner of the base of the columella on either side. Two divergent lines are drawn down to the white roll to end at B1 and B2 as shown (Figure 66.8), B1 and B2 being slightly wider than A1 and A2. Point C is the midpoint between B1, B2 and it is the lowest point of the Cupid's bow. On the cleft side's right and left points, D1 and D2 are marked to represent the commissure of the lips. Points E1 and E2 are marked at the spot where the white roll just begins to fade. Thus, D1–E1 is equal to D2–E2. At E1 and E2, a perpendicular line is drawn towards the free margin of the lip. Points F1 and F2 are marked such that E1–F1 is equal to E2–F2 is equal to B1–C is equal to B2–C. F1–E1 continues along the white roll into the internal aspect of the nostril on either side. The incision is made using a no. 15 blade starting from A1 to B1 and then again on the other side from A2 to B2. The two are joined together across C. The incision goes through the skin and incorporates a little of the underlying tissue. On the cleft sides, that is the lateral sides, incisions are started at E1 and continued along the white roll into the nostril and extended laterally to the point F1. At E1, the incision is also taken perpendicular to the white roll to the free margin of the mucosa and a mucosal flap is elevated on right side. A similar flap is elevated on the left side.

Once the incisions are completed, the orbcularis oris muscle is dissected free from its abnormal attachments on either side of the base of the ala and maxilla. The muscle is freed from its attachments to the skin, mucosa and vermillion using a no. 15 blade up to a distance of about 5 mm (Figure 66.9). Superiorly, where the abnormal



1 – prolabium. 2 – premaxilla. 3 – vomerine stalk. 4 – vomerine mucosa.
5 – osteotomy site. 6 – vomer exposed. 7 – osteotomy site after reduction.
8 – resorbable bone plates.

Figure 66.5 Premaxillary osteotomy.



(a)

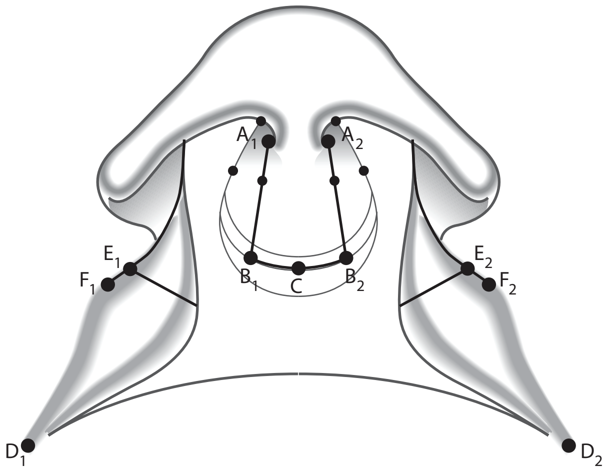
(b)

Figure 66.6 (a and b) Model analysis prior to premaxillary osteotomy.

(a)

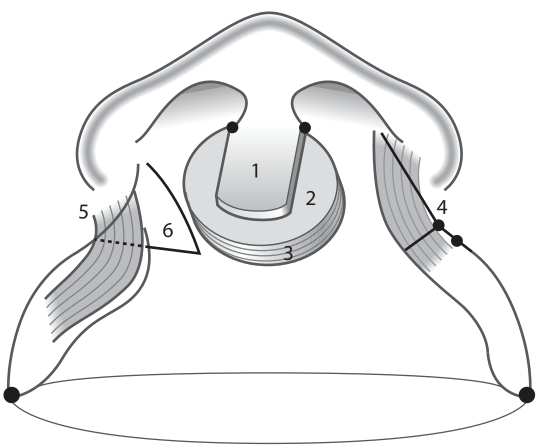
(b)

Figure 66.7 (a) Pre- and (b) post-operative photographs.



A_1 A_2 – junction of columella with prolabium.
B_1 B_2 – highest point of Cupid's bow. C – lowest point of Cupid's bow.
D_1 D_2 – commisure of lip. E_1 E_2 – white roll fades.
F_1 F_2 – back cut along white roll such that E_1 F_1=E_2 F_2=B_1 C=B_2 C.

Figure 66.8 Anatomic points for lip marking.



1 – prolabial skin flap. 2 – excess skin and mucosa. 3 – premaxilla.
4 – unoperated side showing orbicularis oris muscle bundle under intact skin/mucosa. 5 – exposed orbicularis oris muscle.
6 – mucosa elevated.

Figure 66.9 Muscle dissection.

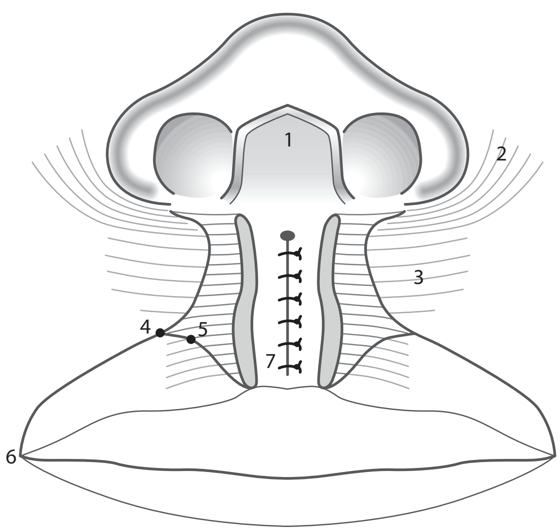
insertion of the muscle into the ala is seen, the muscle is freed using a combination of sharp and blunt dissection to free the entire corpus of orbicularis oris muscle along with the bundles of the nasalis and the other associated muscles. To mobilize the lip completely, the muscles are also freed from the underlying maxillary bone in a subperiosteal manner. The orbicularis and nasalis muscles are freed as far as the base of the alar margin and a sulcular incision is made into the depth of the sulcus from the free margin of the lip up to the premolar area. The subperiosteal dissection is carried out to elevate the entire lip complex along with its underlying and associated muscles away from the maxillary wall. The tissues are freed along the pyriform margin and also extended into the lateral aspects of the ala of the nose on either side. The incision along the white roll towards the nostril is carried on until it reaches the inferior aspect of the inferior turbinate mucosa. The mucosal flaps are raised to coincide with the nasal layer of the anterior aspect of the palatal mucosa. On the prolabial side, the incision B1–A1 is carried further backwards along the nasal mucosa over the vomer bone, such that the nasal flaps can be elevated on either side. This helps in having a continuous nasal lining from the palate forwards into the lip. As soon as the mobilization is complete, it will be seen that the lateral segments of the lip now assume a very comfortable horizontal position and they can be brought together with minimal or no tension at all. The excess lip mucosa which is medial to points E1 and E2 is used to form the sulcus of the future upper lip.

MOBILIZATION OF NASAL CARTILAGES

Blunt dissection of the lateral crura of the lower lateral cartilages on either side using a curved blunt-tipped tenotomy scissors. The scissors are placed through the lateral incision and blunt dissection is proceeded along the superior and inferior and the outer and inner aspects of the lower lateral cartilage up to the dome (intermediate crura). The medial crura of the lower lateral cartilage is approached from the prolabial side and also freed on all aspects. This mobilizes the lower cartilage completely and allows it to attain its natural form during closure of the lip.

CLOSURE

Closure is performed in three layers (Figure 66.10). First, the nasal layer is closed in continuity with the closure of the



1 – elevated prolabium. 2 – nasalis muscle.
3 – orbicularis oris muscle. 4 – point F_1. 5 – point E_1.
6 – commisure point D.
7 – mucosa sutured with 4.0 vicryl

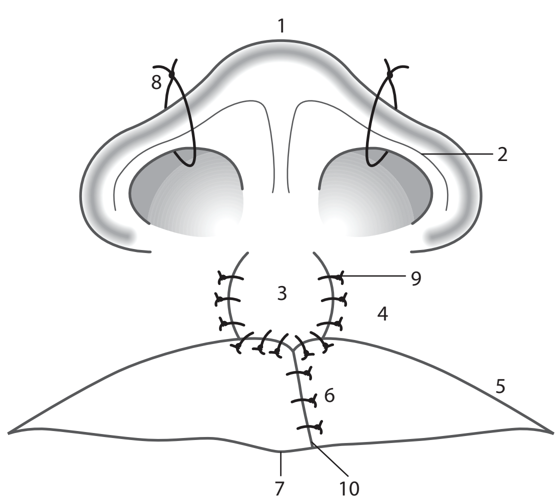
Figure 66.10 Closure of nasal layer and apposition of the muscles.

premaxillary nasal mucosa which was performed earlier. Once the nasal layer closure is complete, the mucosa on the inner aspect of the upper lip on either side is sutured to the prolabial mucosa to form the sulcus of the oral cavity. Closure is obtained using 4/0 Vicryl sutures (5/8 of a circle cutting needle).

The next layer of the closure is the muscle. The nasalis is identified on either side by pulling it medially and seeing the inwards movements of lower lateral cartilage and the base of ala on either side. The orbicularis oris proper muscles are also identified and three sutures are placed using 4/0 Vicryl to bring together the orbicularis and nasalis muscles comfortably in the midline over the prolabial mucosa. Along its length, skin hooks are positioned actively, giving a slight downward traction to the lip, to ensure that the entire nasalis and orbicularis muscles have been brought together.

SKIN CLOSURE

The prolabial skin is allowed to fall gently upon the closed orbicularis muscles, and the two lateral segments are then gently pulled across and held together with two skin hooks held in parallel along the long axis of the body of the patient (Figure 66.11). Any excess skin in the lateral segments resulting from the closure of the muscles can be incised to accommodate the prolabial skin in the midline and the wound is closed using 5/0 proline sutures. The vermillion and the oral mucosa are closed using 4/0 Vicryl. Care is taken to achieve a central tubercle in the midline of the lip, thus giving the upper lip a pleasant and natural appearance. Bolster sutures are placed through the dome (intermediate crura) of the lower lateral cartilages to hold them up in a new position allowing the skin and the mucosa to adapt and heal in the new relaxed positions of the cartilages. The skin sutures and bolster sutures are removed after 7 days.



1 – dome. 2 – lower lateral cartilage. 3 – prolabial skin.
4 – lateral element skin. 5 – Cupid's bow. 6 – vermillion.
7 – central tubercle. 8 – bolster stitch with 3.0 prolene.
9 – skin closure with 5.0 prolene.
10 – mucosal closure with 4.0 vicryl

Figure 66.11 Skin closure.

POST-OPERATIVE CARE

Steri strips are placed immediately after the suturing and they are removed after 2–3 days to inspect the wound and clean it. The wound is meticulously cleaned with normal saline and hydrogen peroxide and betadine and steri strips are replaced. On the seventh day, the sutures are removed under sedation, the wound is cleaned again and new steri strips are placed. The parents are advised to apply vitamin E cream to the wound post-operatively for a period of 3 months and massage the lip gently every day. Gentle massage of the lips is continued for at least 3 months.

RESULTS

The results of primary closure of bilateral cleft lip surgery are shown in a series of different patients in Figures 66.12 through 66.15.

COMPLICATIONS

Intra-operative

FRACTURE OF THE PREMAXILLA

The premaxilla is continuous with the vomer along a very thin stalk and may sometimes be traumatized, especially if it is protuberant either prior to the surgery or during the procedure.

AVULSION OF THE PREMAXILLA

This is a rare, but unacceptable, iatrogenic complication.

Post-operative

EARLY

Infection

The wound may get infected, especially in chronically malnourished children in developing countries due to decreased immunity. Use of antibiotics and local wound management should salvage the surgical procedure.

Dehiscence of the wound

As a sequela to either wound infection or tension during closure, partial breakdown of the surgical repair may occur. Conservative management is followed by secondary correction after 6 months.

LATE

Oronasal fistula

Partial breakdown of the nasal layer may lead to small oronasal communications in the region of the premaxilla and lateral segments. Definitive repair of the fistula

(a)

(b)

Figure 66.12 Pre- and post-operative photographs. (a) Preoperative and (b) postoperative.

(a)

(b)

Figure 66.13 Pre- and post-operative photographs. (a) Preoperative and (b) postoperative.

(a)

(b)

Figure 66.14 Pre- and post-operative photographs. (a) Preoperative and (b) postoperative.

(a)

(b)

Figure 66.15 Pre- and post-operative photographs. (a) Preoperative and (b) postoperative.

in two layers is taken up as a secondary procedure after 6 months.

Cupid's bow deformity

Mismatch of the white roll during suturing or wound contracture may lead to a deformed Cupid's bone, which is corrected with Z-plasties or scar revision.

Whistling deformity

Generally, this is a severe deformity due to inadequate mobilization of nasalis and orbicularis oris muscles or dehiscence of these muscles due to closure with tension. Secondary repair is carried out in the form of a complete revision cheiloplasty.

Hypertrophic scar

Hypertrophic scar is a common sequel due to excessive tension in skin closure and is all the more apparent in pigmented skin (types IV–VI). Hypertrophic scars can be managed initially conservatively using vitamin E cream, massage, contratubex ointment etc. Minimally hypertrophic scars can be resurfaced with erbium YAG lasers. Severely hypertrophic scars would need excision and resuturing in a tension-free environment.

MOBILIZATION – OPEN TECHNIQUE

The incisions of the lip which extend in to the nasal cavity along the inferior margin of the lower lateral cartilage is continued to meet the prolabial incision at the medial crude. This allows a complete reflection of prolabial and columellar skin to expose the dorsal aspect of the right and left lower lateral cartilages completed up to its attachments laterally to the pyriform rim.

Next, the nasal mucosa is freed from the inner aspect of the lower lateral cartilages from lateral to medial to mobilize the lateral crura completely. The superior end of the lower lateral cartilage is freed from its fibrous overlapping attachment with the upper lateral cartilage.

The lateral crura is now free floating whilst the medial crura continues to be attached to the columellar mucosa.

An interdomal stitch is taken after medialization of the two lateral crura such that, a new better projected nasal tip is achieved.

Closure is then achieved by redrawing the columelloprolabial skin, and suturing the infra-cartilaginous incision.

The rest of the lip, nose correction is exactly as before.

The nasal septum is generally addressed at the same time and it is excess mobilized and trimmed along the axillary crest.

This allows the septum to swing freely and reposition itself in the midline as balance is restores between two sides of facial and lip muscles.

There was a hypothetical concept that nasal and facial growth might be affected if an open lip, nose correction were to be performed. However, this is not the case as can be seen in 10-year follow-up of patients.

The results of mobilization – open technique is shown in Figures 66.16 and 66.17.

(a) (b)

Figure 66.16 (a) Pre- and (b) post-operative photographs of a patient treated with the 'open' technique.

(a)

(b)

(c)

Figure 66.17 (a,b) Pre- and (c) post-operative photographs of a different patient treated using the 'open' technique.

Top tips

- The prolabium is devoid of muscle.
- The premaxilla may be situated centrally or asymmetrically in three dimensions.
- The ideal age of repair of the bilateral cleft lip is 3 months, but patients may present at any age in less informed societies.
- There are several techniques to manage the premaxilla which include simple strapping (common), nasoalveolar moulding (common), lip adhesion (less common) and premaxillary osteotomy (occasionally).
- In the definitive repair of the bilateral cleft lip, it is important to first repair the nasal floor.
- Further important steps include careful marking of the incisions and meticulous mobilization of the muscles.
- The lip–nose complex is treated simultaneously and hence careful closed dissection and mobilization of the lower lateral cartilages are performed.
- During mucosal closure, care is taken to achieve a good sulcus and, on the labial side of the alveolus, a gingivoalveolar periosteoplasty is achieved.
- Skin closure achieves symmetry of the lip and nose, and pleasing Cupid's bow, philtral ridges and central tubercle.
- Potential complications though rare include intraoperative fracture or avulsion of premaxilla, postoperative infection or dehiscence of the wound, and late problems such as oronasal fistula, whistling deformity, hypertrophic scars etc.

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67

Primary repair of cleft palate

CHRISTOPH T HUPPA

CONTENTS

INTRODUCTION

The first major step towards modern cleft palate surgery was made in 1862 by Bernhard von Langenbeck[1] (1810–1887) at the Charité in Berlin. He suggested closing the palate with two medially mobilized bipedicled mucoperiosteal flaps. In principle, this method is still in use today.

With the invention of local anaesthetic, surgical procedures could be refined as speed was no longer an issue. The first significant modification was introduced by F. Ernst in 1925 who suggested suturing of the muscles, division of the palatine vessels and the formation of parapharyngeal pouches to reduce tension to the midline sutures.

Victor Veau from Paris refined the procedure in 1931 by dissecting the nasal mucosa, thus closing the soft palate in three layers. He furthermore developed a method using posteriorly based unipedicled flaps which helped to lengthen the velum according to the principle of a V–Y plasty. A similar procedure was developed by the British surgeons Kilner[2] (1890–1964) and Wardill[3] in the late 1920s and early 1930s. In 1959, this so-called 'pushback' procedure was modified by Widmaier[4] who suggested a supraperiosteal dissection of the flaps to reduce growth impediment of the maxilla. He introduced the use of a caudally based vomerine flap, first described by the British surgeon A. Campbell in 1926, to close the hard palate.

In 1970, the German surgeon Kriens[5] from Hamburg published an article emphasizing the importance of an anatomically correct repair of the velar muscles which includes the detachment of the wrongly inserted musculature from the posterior aspect of the palatine bone. This concept of an intravelar veloplasty is still the basis of most modern techniques in primary and secondary cleft palate surgery.

In the 1950s, the ear, nose and throat (ENT) surgeon Wolfram Schweckendiek pioneered a method of a two-stage repair, previously described by Gillies and Fry[6] in 1921, which included an early soft palate and a late hard palate repair to prevent maxillary growth

disturbances which had been seen in many cases with the previous techniques. According to his protocol, he carried out the hard palate repair on a patient aged 12 years. Schweckendiek[7] popularized this two-stage procedure in many cleft centres worldwide when he published excellent long-term results in 1978.

In 1976, Leonard T. Furlow introduced a completely different method involving a double opposing Z-plasty to close and simultaneously lengthen the soft palate. This procedure had already been published in principle in 1966 by Karl Schuchardt. When Furlow[8] presented some very encouraging results in 1986, the method gained popularity and is nowadays a very well-established procedure in many cleft centres around the world.

PRINCIPLES

The main target of the primary repair of the cleft palate is to reinstate the function of the soft plate. This is most important as the formation of certain speech sounds requires normal function of the velum. During the formation of, for example, explosives like [b], [p], [d] and [t], the nasal airway has to be sealed off by a craniodorsal movement of the soft palate. If this is not possible air escapes through the nose and the air pressure, which is necessary to form these sounds, cannot build up and speech sounds hypernasal. A nasal air escape can be noticed. This pathophysiological phenomenon is called velopharyngeal insufficiency (VPI) or velopharyngeal dysfunction (VPD). Therefore, it is paramount to repair the velar muscle layer in an anatomically correct position as pointed out by Otto Kriens in the 1960s.

A measure for VPI is the nasalance which is a quotient of nasal and oral acoustic energy. It can be measured by a nasometre (acoustic energy) or an aerophonoscope (air flow).

In order to lay the foundations for normal speech development, the repair of the soft palate should be carried out before onset of speech, i.e. in the first year of life.

A no less important aim of palate repair is to install the natural separation of the oral and nasal cavities and to establish two separate nasal cavities. This avoids nasal regurgitation of food, which can be socially very troublesome and prevents contact of food with the nasal mucosa.

On the other hand, an early intervention could lead to maxillary growth retardation and hypoplasia especially if the alveolar periosteum is detached during the procedure.

For this reason, some cleft surgeons advocate closure of the hard and soft palate in separate procedures. There is still some controversy about the question of whether a one- or two-stage palate repair is preferable. The two most common basic protocols are as follows:

1. Lip repair (uni- or bilateral) at the age of 3–6 months followed by a one-stage hard and soft palate repair at the age of 6–12 months
2. Lip repair (uni- or bilateral), in combination with soft palate repair followed by a hard palate repair at age 15 months to several years (in extreme cases, early teens)

In a two-stage procedure, early periosteal stripping of the hard palate can be avoided; however, it is still unclear if this gives a significant advantage for the midfacial growth. In fact, some scientific studies suggest that differences in maxillary growth might not be significant. The disadvantage of persistent nasal regurgitation of food and fluids has to be taken into account.

Despite all the improvements in cleft palate surgery, in many cases, speech and language therapy may still be needed to obtain a good result, but a significant proportion of patients can develop normal speech without any further therapy. Some patients may need further surgery for speech improvement later in life. Speech can still deteriorate during growth periods, such as the early teens, and special precaution has to be taken when planning maxillary advancement surgery.

Primary repairs in adulthood have been shown to be much less successful with regards to speech, but can still be helpful for the better functioning of dentures and to avoid nasal regurgitation of food.

ANATOMICAL CONSIDERATIONS

The physiological functioning of the soft palate is essentially due to an anatomically correct restoration and reorientation of the velar musculature which has to be detached from the posterior aspect of the palatine bone. Important muscles of the soft palate are as follows:

- *Levator veli palatini*, which originates from the petrous portion of the temporal bone, is attached to the medial wall of the eustachian (auditory) tube and runs ventral to the tensor muscle into the velum to fuse with its counterpart on the opposite side. Its function is to lift the soft palate in a cranioposterior direction. This muscle is most important for the velopharyngeal seal and creates the velar ‘knee’ in a lateral videofluoroscopy. Functionally, it is most effective in a more posterior position.
- *Tensor veli palatini* which originates from the scaphoid fossa of the sphenoid bone and the lateral rim of the eustachian tube runs with a tendon through the sulcus of the pterygoidean hamulus and forms the palatal aponeurosis with the opposite side in the anterior third of the soft palate. Next to stretching the velum, its main function is to open the auditory tube.
- *Musculus uvulae* are a paramedian pair of muscles running from the posterior nasal spine to the tip of the uvula. Supports the levator bulge and thus helps with the oropharyngeal seal.
- *Palatopharyngeus muscle* which forms the posterior pillar of the fauces (pharyngopalatine arch) originates with a wide base from the posterior and lateral pharyngeal wall and inserts with its posterior fasciculus at the posterior aspect of the hard palate and the anterior fasciculus into the soft palate. It can send the small salpingopharyngeus muscle to the eustachian tube, but

this muscle is not always present. Functionally, the palatopharyngeus elevates the pharynx and larynx, constricts the isthmus faucium while swallowing and depresses the soft palate opposing the action of the levator muscle.

- *Palatoglossus muscle* runs from the velar aponeurosis to the posterior superior parts of the tongue. It is another antagonist of the levator muscle and forms the anterior pillar of the fauces (palatoglossal arch).
- *Superior pharyngeal constrictor muscle* arises from the pterygoid hamulus of the sphenoid bone and the pterygomandibular raphe. The fibres run in a backward curve to unite in the median pharyngeal raphe with the opposite side. Its function is a constriction of the upper pharynx in collaboration with the levator veli palatini muscle while swallowing. If hyperplastic, this muscle is the anatomical substratum of the Passavant's ridge. Its significance for speech is doubtful.

PRE-OPERATIVE ASSESSMENT

Most children with cleft lip and palate are otherwise healthy and do not need any further pre-operative precautions. However, in some cases, especially where the cleft palate is part of a syndrome, attention has to be paid to other co-morbidities involving especially the heart or kidneys. Therefore, it is important to have a paediatrician on the team to make sure these conditions are not missed.

Audiology and ENT assessment should be arranged prior to the palate repair as the insertion of grommets can be carried out simultaneously with the palate repair if indicated. As the palate repair can lead to significant haemorrhage, the clotting system should be assessed.

In case the cleft palate is part of a Pierre Robin sequence, pre-operative sleep studies can be helpful. In these cases, pre-surgical orthopaedic therapy with a modified Hotz's plate can be useful to reposition the tongue in a more anterior position. The forward push of the tongue seems to stimulate mandibular growth.

As cleft surgery is in principle elective surgery, it should be carried out under optimal conditions. The procedure should be postponed whenever signs of common cold, respiratory tract infections or other acute medical conditions are seen. The parents need to be warned about this possibility in advance.

ANAESTHESIA

The surgery is undertaken under general anaesthetic which should be administered by an experienced paediatric anaesthetist. Due to their small body volume, infants are at much greater risk from hypothermia than adults. A temperature probe should be inserted and the infant has to be kept warm throughout the procedure. Monitoring during the entire surgery is most important.

For ventilation, an orotracheal tube is used and it should be fixed in the middle of the lower lip so it can be protected by the tongue spatula of the self-holding retractor (Dingman or similar). As paediatric endotracheal tubes do not have a cuff, it is paramount to prevent any gas leakage or fluid aspiration with a carefully placed throat pack.

To prevent a peri-operative wound infection, a single shot of an antibiotic (co-amoxiclav, combination of cephalosporin and metronidazole or similar) at induction is usually sufficient.

As the palate repair is physiologically stimulating for the infant, local anaesthetic with epinephrine (adrenaline) (2% lidocaine with 1:80,000 epinephrine or similar) should be infiltrated into the soft and hard palate at the beginning of the procedure to reduce the amount of general anaesthetics and to induce vasoconstriction in the surgical field.

Extubation is the most critical moment after palate repair and the infant has to be closely monitored during this process and during the first night afterwards. As the nasal airway resistance rises due to the surgery, the infants may experience airway problems and a nasal prong may have to be used. If this is at all necessary, it can be removed, in most cases, the next day as the infant adapts to the new situation and the post-operative oedema of the nasopalatal mucosa settles.

In children with Pierre-Robin sequence, however, it is sometimes necessary to keep the nasal airway for a while.

OPERATIVE PROCEDURE

There are a number of different surgical procedures available to close the cleft palate. The classical palate repair based on bilateral bipedicled von Langenbeck flaps, the Furlow repair and the two-stage Schweckendiek repair will be described in detail in ‘Two-stage procedure (Schweckendiek)’.

Repair using bipedicled langenbeck flaps (Langenbeck–Ernst–Veau–Kriens repair)

Positioning of the patient and local anaesthesia

The patient rests in a supine position with a bulky gel pad or fluid bag underneath the shoulder. The neck has to be extended as much as possible to make sure the surgeon has good access to the palate and sits comfortably in the 12 o’clock position with the infant's head in his lap. The assistants sit at 9 and 3 o’clock (Figure 67.1). It is advisable to wear a head light.

The first step of any palate repair is the insertion of a self-holding retractor (Dingman or similar) which serves as a mouth gag, retracts the tongue and cheeks and protects the orotracheal tube (Figure 67.2). Once the retractor is in its final position, sufficient ventilation has to be confirmed by the anaesthetist.

Figure 67.1 The surgeon's position at 12 o'clock with the infant's head in his lap.

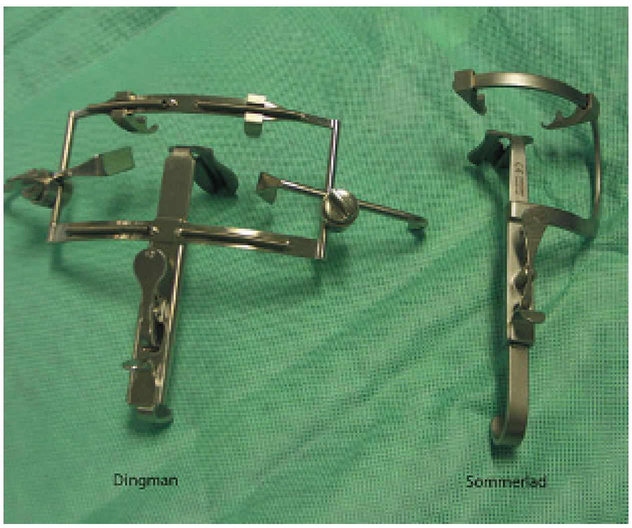

Figure 67.2 Different types of self-holding retractors.

The local anaesthetic is injected into the mucosa of the hard and soft palate. In order to give the adrenaline time to be effective, one should wait with the first incision until the bleeding in the injection channels stops.

MUCOSAL INCISIONS AND FORMATION OF BIPEDICLED LONGITUDINAL FLAPS

The procedure is started with the surgeon's right hand at the patient's left-hand side. Using a size No. 15 blade, an incision is made along the borderline of the oral and nasal mucosa with excision of a little mucosal triangle at the medial aspect of the hemi-uvula (this creates a contact surface for the unification of both hemi-uvulae) (Figure 67.3). In the area of the hard palate, the incision goes right on to bone.

In wider clefts, lateral releasing incisions in the transition zone between alveolar and maxillary mucosa are necessary

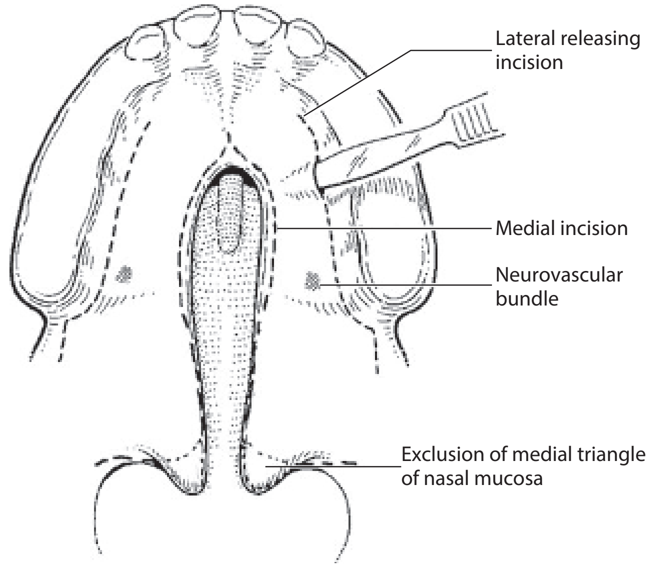

Figure 67.3 Incisions for formation of bipedicled longitudinal flaps.

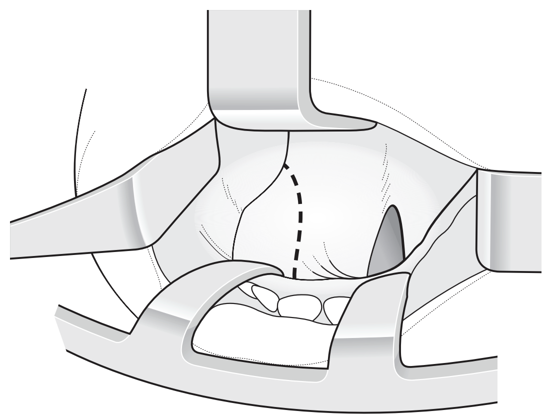

Figure 67.4 Marking for the left lateral releasing incision.

and should extend from the area above the space of Ernst posteriorly to the level of the anterior extension of the cleft (Figure 67.4). The incision is made right on to bone and an anterior pedicle should be preserved at this stage. The flap is now undermined subperiosteally with a curved sharp elevator and after thorough haemostasis the neurovascular bundle is luxated a few millimetres out of the palatine canal using a curved elevator anterior and posterior to the bundle. This step can be rather frightening for the inexperienced surgeon, but it is important because otherwise the flap cannot be mobilized towards the midline without tension. Care has to be taken in order not to damage the palatine artery.

MUSCLE DISSECTION AND FORMATION OF A NASAL MUCOSAL LAYER

The muscle dissection and precise reconstruction are of paramount importance and should be carried out as carefully as possible. Loops with a magnification factor

of 2.5–3.5 or a surgical microscope are most useful, but not indispensable.

The dissection begins with the detachment of the wrongly inserted musculature from the posterior aspect of the palatine bone. This is best undertaken with a sharp Freer's periosteal elevator and a Mitchell's trimmer. The nasal mucosa is detached from the nasal aspect of the palatal shelf with a fine sharp curved periosteal elevator to stretch it to the midline and thus make the closure with the opposite side possible.

The muscle is then lifted up with a skin hook and kept under tension to be dissected off the nasal mucosa laterally as far as the pterygoid plates. The dissection can be carried out with a pair of sharp pointed scissors or a size No. 15 blade. It is important to keep the musculature attached to the oral mucosa because otherwise the blood supply to the mucosa can be compromised and oronasal fistulas are more likely to occur.

After analogous dissection on the patient's right side with the surgeon's left hand, an incision is made along the vomerine ridge with small release incision posteriorly at an angle of about 45° (Figure 67.5). The mucosa tends to bleed quite intensively due to its excellent blood supply.

Small vomerine flaps are formed and each of them is united with its adjacent counterfoil of nasal mucosa across the cleft using 5-0 monofilament resorbable sutures (Monocryl® or similar). The stitches should be inserted indirectly in order to place the knots towards the nasal cavity, so that two separate tubes of nasal mucosa are formed (Figure 67.6).

Next, the nasal mucosa of the velar area should be repaired from front to back in the same way using the same sutures.

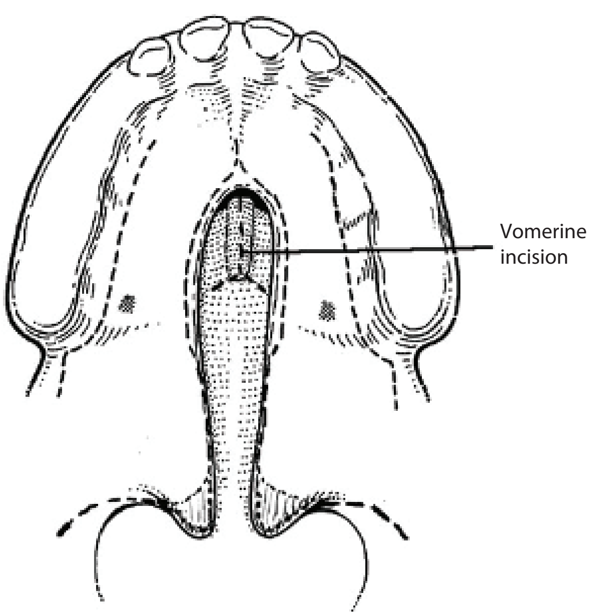

Figure 67.5 Incisions for the formation of bilateral vomerine flaps.

MUSCLE REPAIR

The muscle repair is the most important step and should be carried out with slowly resorbing monofilament sutures (4-0 polydioxanone, i.e. PDS® or similar). Corresponding parts of the musculature are stitched together starting from the back to the front with three to four sutures. It is important to achieve a symmetrical result at this stage and the oral mucosa should align without tension after the completion of the muscle repair. As a result of the repositioning of the muscle in a more natural posterior position, there should be a significant gap between the anterior aspect of the repaired muscle and the posterior ridge of the palatine bone.

REPAIR OF THE ORAL MUCOSA

The oral mucosa should be closed with 5-0 monofilament resorbable sutures. It is best to start the repair of the oral mucosa with two to three deep stitches which engage all layers (use 3-0 monofilament resorbable sutures) in the area of the hard/soft plate junction (Figure 67.7). They are placed and temporarily fixed with an arterial clip from back to front to be then tied one after the other from front to back. This is important to avoid a haematoma between the different layers which again reduces the risk of fistula

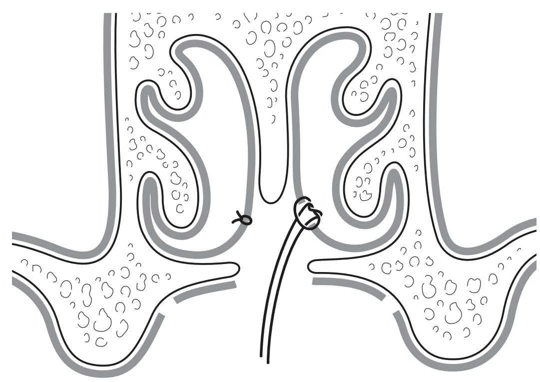

Figure 67.6 Cross section of the anterior palate, reconstruction of two separate nasal tubes with vomerine flaps.

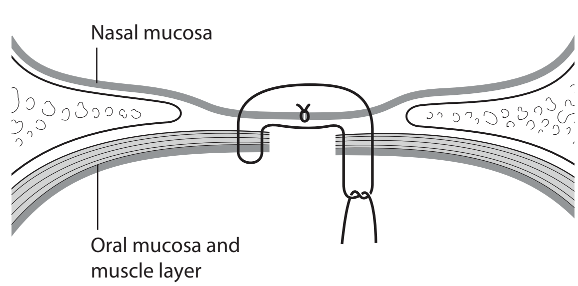

Figure 67.7 Cross section of deep stitches at junction hard/soft palate to close down dead space and avoid haematoma formation.

formation. Furthermore, these stitches help to shape the typical palatal vault.

Next, the first 5-0 stitch is applied to the tip of the uvula. It should be used as a stay suture which can be attached to the retractor or clamped to the head towel (Figure 67.8). Following this, the stitches to the posterior aspect of the uvula can be put in easily. The stay suture is cut short and the oral mucosa can now be sewn without any tension from the back to the front using mattress stitches all along.

If the cleft is very wide, it is sometimes necessary to sacrifice one or even both of the anterior pedicles to close the anterior mucosa of the hard palate which would otherwise not be possible (Figure 67.9).

MANAGEMENT OF LATERAL RELEASE INCISIONS

To avoid post-operative haemorrhage from the lateral releasing incisions which remain at least partly open, some sort of haemostatic sponge (Surgicel®, Spongostan® or similar) can be introduced. They are fixed with two or three retaining stitches which should not be tied too tight in order to avoid tension at the primary closure site in the midline (Figure 67.10).

The releasing incisions will heal through free granulation and cannot be distinguished from the local mucosa with the naked eye after a few weeks.

Two-stage procedure (Schweckendiek)

The advantage of a two-stage palate repair is the fact that the velum can be closed before onset of speech without undermining the palatal periosteum which might lead to growth retardation. In theory, good speech results can be achieved without compromising on maxillary growth.

The velar incisions are similar to the von Langenbeck procedure, but the incision line at the border of oral and nasal mucosa stops in the area of the hard and soft palate junction to turn laterally at a right angle. Lateral to the pterygoid hamulus, a small back cut in the posterior direction is advisable.

The incorrectly inserted musculature has to be detached from the posterior aspect of the palatine bone (Freer, curved periosteal elevator) followed by a sharp dissection off the nasal mucosa with a blade or pointed pair of scissors (Figure 67.11).

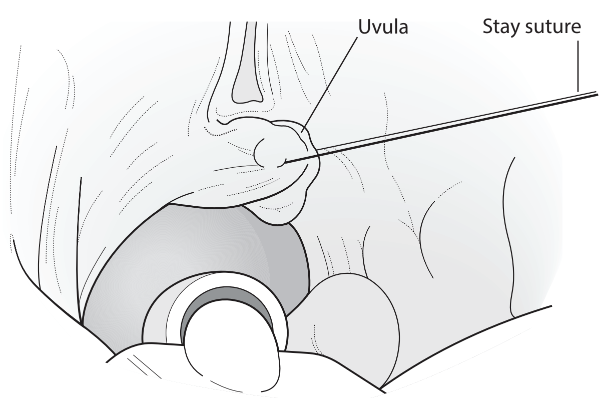

Figure 67.8 Tip of the reconstructed uvula fixed with a stay suture to access posterior aspect of the uvula for closure.

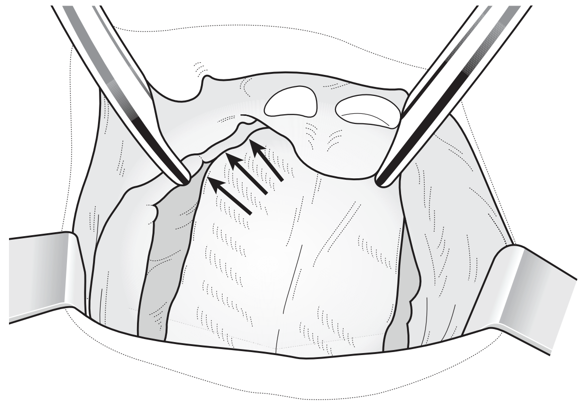

Figure 67.9 Wide alveolar cleft closed with the right detached anterior pedicle (arrows).

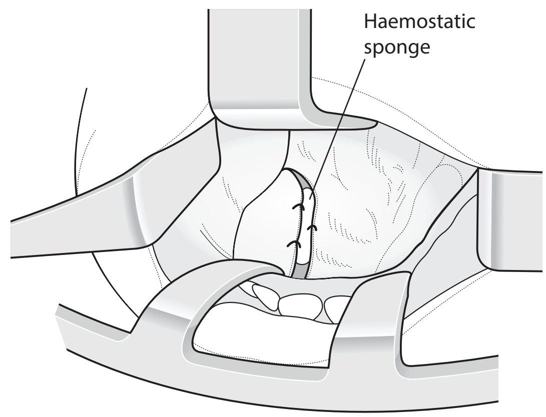

Figure 67.10 Left lateral releasing incision with haemostatic sponge *in situ*.

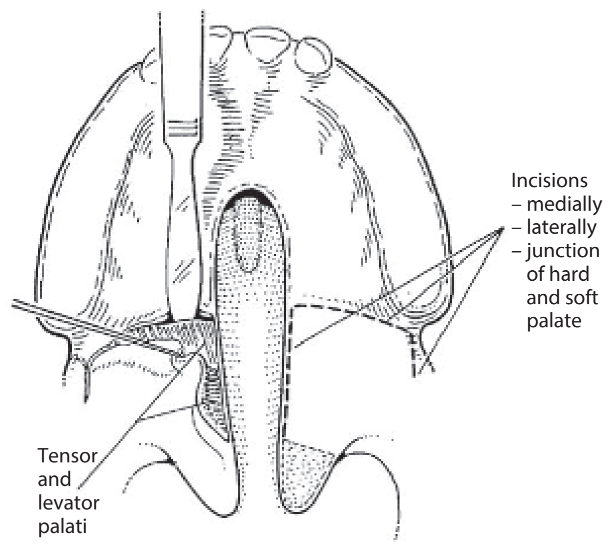

Figure 67.11 Incisions for stage one of two-stage procedure (isolated soft palate repair).

The next step is the repair of the nasal mucosa with 5-0 monofilament resorbable (Monocryl or similar) interrupted sutures. As previously mentioned, the knots should be placed towards the nasal cavity. The muscle is now repaired as described for the one-stage procedure. The last step is the repair of the oral mucosa with 5-0 monofilament stitches in analogy to what was mentioned earlier.

In wide cases, an oral mucosa gap will remain at the hard and soft palate junction parallel to the posterior border of the palatine bone. It should not be closed with tight stitches as this would shorten the velum. In these cases, some resorbable haemostatic foam (Surgicel, Spongostan or similar) can be introduced and fixed with some retention sutures.

As a result of this repair, a scar forms in transverse direction. This could lead to a narrowing of the posterior hard palate due to scar contraction.

CLOSURE OF THE HARD PALATE

The closure of the remaining hard palate defect is carried out according to the particular protocol between 18 months and about 13 years of age. Nowadays, the tendency goes more towards early repair. Quite often, one will only find a relatively narrow but longitudinal defect as the gap tends to decrease with time. If the protocol involves a relatively late repair of the hard palate, a cover plate should be considered to reduce the inconvenience caused by the remaining oronasal communication.

The surgery is performed under general anaesthesia and follows the principles of a fistula repair. A two-layer closure is desirable. In order to create a nasal layer, the nasal mucosa has to be stretched and/or mucosa from the oral cavity has to be borrowed and turned over into the nasal floor. The remaining increased defect of the oral mucosa can then be closed with a rotation or sliding flap (similar to von Langenbeck flap) (Figure 67.12). It is important to design the oral mucosa flap as large as possible to avoid the reappearance of an oronasal fistula.

REPAIR WITH DOUBLE OPPOSING Z-PLASTY (FURLOW)

This technique follows a completely different approach to close the cleft palate. It uses an oral layer and a nasal layer Z-plasty that oppose each other. Thus, a lengthening of the palate, as well as a reorientation of the muscles, can be achieved. The major disadvantage is that it produces an asymmetrical scar which is partly transversely orientated and could lead to some narrowing of the maxilla.

In a first step, a large Z-plasty is designed in the area of the velum with the end points of the lateral limbs lying in the area of the pterygoid hamuli, which can be palpated through the mucosa. The central limb lies parallel to the cleft (Figure 67.13).

The posteriorly based triangle has to be prepared as a myomucosal flap containing oral mucosa and tensor, as well as the levator veli palatini muscles. The muscles have to be detached from the posterior aspect of the palatine bone with a sharp Freer's elevator or Mitchell's trimmer and dissected off the nasal layer which stays intact at this stage. Nasal and oral mucosa have to be elevated from the bony shelves of the hard palate with a curved periosteal elevator, Mitchell's trimmer or Freer's (Figure 67.14).

The opposite side in now dissected in the opposing way leaving the musculature attached to the nasal layer (Figure 67.15).

Next, the opposing nasal Z has to be designed with the end points of the lateral limbs situated just a few millimetres medial to the mouth of the eustachian tube. As a

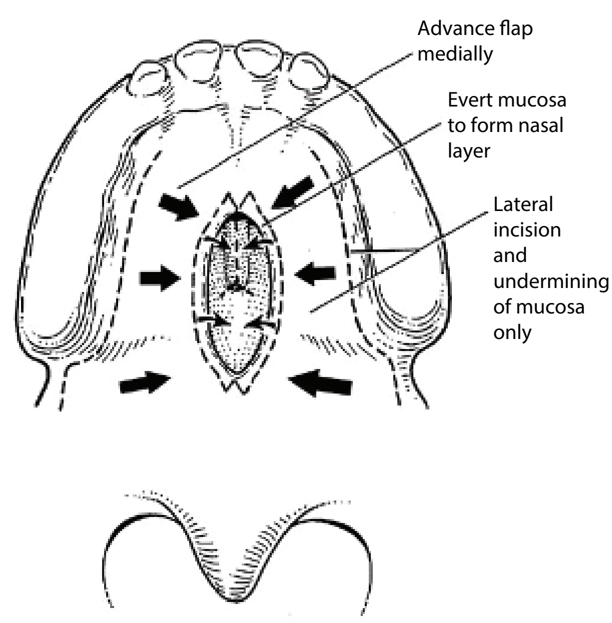

Figure 67.12 Incisions for second stage of two-stage procedure (hard palate repair).

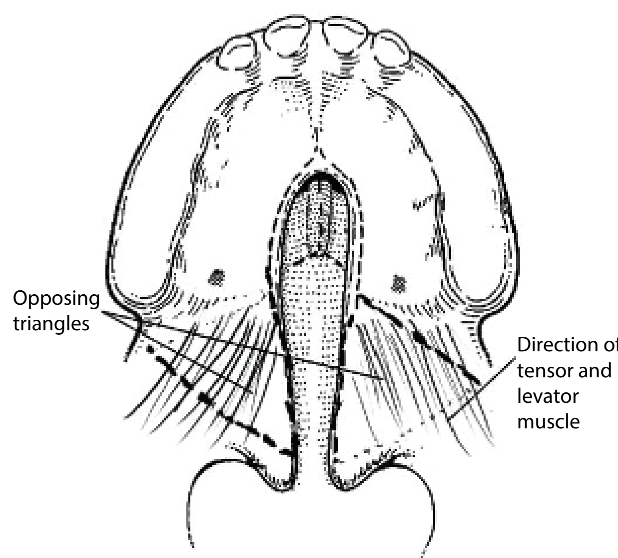

Figure 67.13 Incisions of oral mucosa for repair with double opposing Z-plasties (Furlow). Please note the sagittal direction of tensor/levator fibres.

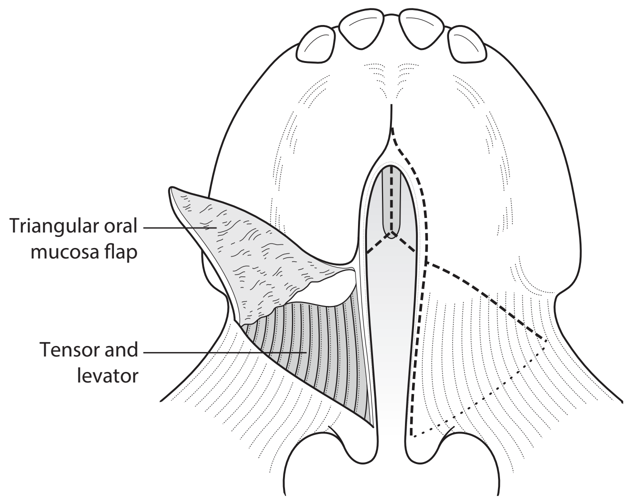

Figure 67.14 Dissection of anteriorly based triangle of oral mucosa at the right-hand side.

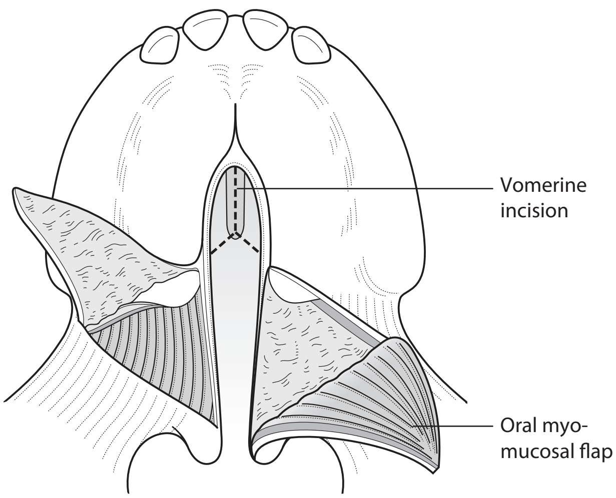

Figure 67.15 Dissection of posteriorly based oral musculo-mucosal triangular flap at the left-hand side.

result, a posteriorly based oral myomucosal flap opposes an anteriorly based oral mucosa flap (Figure 67.16).

The nasal Z-plasty now has to be completed, creating a posteriorly based nasal myomucosal flap. As already performed on the opposite side, the muscle has to be detached from the posterior aspect of the palatine bone. Next, the Z-plasty flaps can be transposed, interposing the corresponding mucosa flap between the posterior aspect of the palatine bone and the myomucosal flap. A 4-0 monofilament stay suture is now placed through the base of the oral myomucosal flap engaging the tip of the nasal myomucosal flap and going back through the oral mucosa. This leads to an overlap of the musculature thus creating a muscle sling (Figure 67.17).

The nasal mucosa is now closed with a 5-0 monofilament resorbable suture and the stay suture can be tied (Figure 67.18).

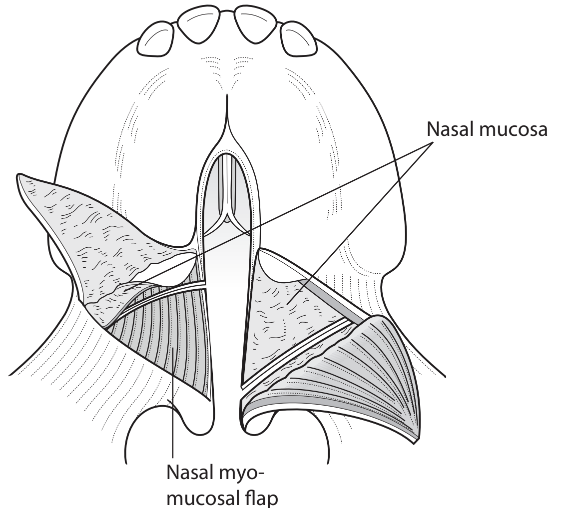

Figure 67.16 Dissection of anteriorly based triangular nasal mucosa flap at the left and posteriorly based triangular nasal musculo-mucosal flap at the right-hand side.

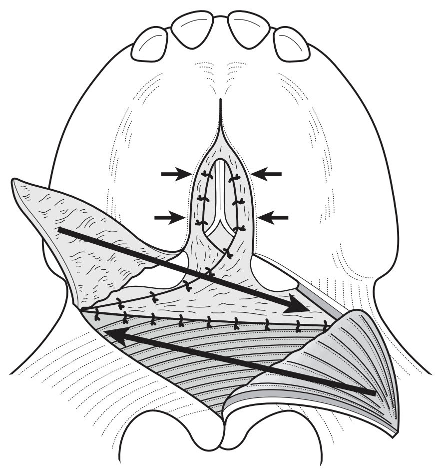

Figure 67.17 Situation after anterior nasal mucosa closure under formation of two separate nasal tubes and exchange of nasal triangular flaps just before exchange of oral triangular flaps in opposite direction (long arrows).

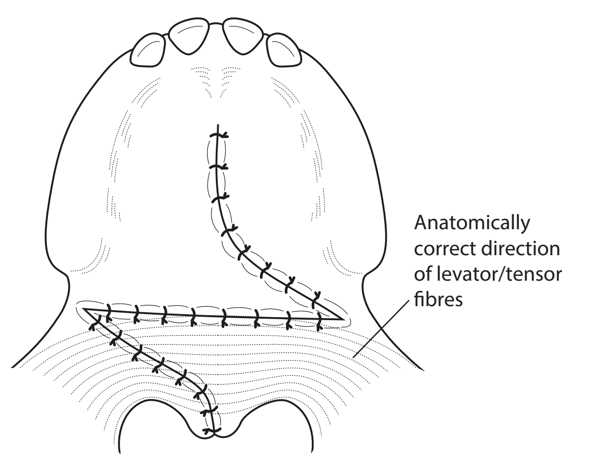

Figure 67.18 Situation after closure of oral mucosa. Please note the transverse direction of tensor/levator muscle fibres.

The undermined mucosa of the hard palate can be closed in analogy to the above described procedure. A repair without tension, however, is not possible in very wide clefts as lateral releasing incisions are not provided.

The final result is a z-shaped scar with a transverse direction of the central limb is obtained. This procedure could be carried out in two stages, closing the soft palate first, leaving the hard palate open for a later repair.

Furthermore, it can be used as a modification in secondary palate surgery if lengthening of the velum as well as an intravelar veloplasty is required.

POST-OPERATIVE CARE

For post-operative pain control, body weight adjusted intravenous (iv) morphine administered by a pump as nurse-controlled analgesia (NCA) overnight is beneficial. Usually the morphine can be stopped after 24 hours and it should be replaced by regular paracetamol and ibuprofen for about 7 days. Under this regime, post-operative drinking and feeding is usually not a problem and should be encouraged immediately after the procedure. However, it is not unusual that infants refuse fluids and get on much better with puréed food as sucking can be more uncomfortable than feeding from a spoon.

The infants should be monitored with pulse oximetry during at least the first 24 hours after the procedure, as post-operative swelling and a naturally increased nasal airway resistance could lead to hypoxia. The post-operative administration of antibiotics is usually not necessary in otherwise healthy children.

PROGNOSIS

Generally, speech and growth outcome after cleft palate repair have improved significantly over the last decades. The question of whether a single- or two-stage repair produces consistently better results has still to be answered. There is more agreement among cleft surgeons about the timing of the soft palate closure. An early repair before the onset of speech in the first year of life seems to lead to the best speech results. Nevertheless, a good proportion of children with cleft palate need speech and language therapy and should be regularly monitored for their speech outcome starting at the age of about 2 years. A minority of these children will need further surgery at a later stage to improve speech or to treat maxillary hypoplasia.

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68

Secondary cleft surgery

JOHN F CACCAMESE, JR

CONTENTS

INTRODUCTION

Secondary cleft surgery can present a reconstructive challenge significantly greater than that of the initial deformity. The surgeon is frequently managing post-surgical deformities after having little or nothing to do with the primary procedure as teams and protocols evolve over time and surgeons move. International 'mission' surgical revision poses the additional challenge of under-qualified surgeons performing cleft surgery in suboptimal conditions resulting in scarring and acquired deformities that are exponentially more difficult to deal with. The cleft surgeon must be a student of the techniques of past years such that they are able to deal with the unique challenges of scarring and compromised blood supply present in these previously operated patients. Additionally, one must stay abreast of one's own outcomes so that appropriate and effective secondary surgery can be offered to your patients with reasonable expectations.

EVALUATION AND CORRECTION OF SECONDARY CLEFT LIP DEFORMITIES

The appearance and function of the mended cleft lip are greatly impacted by the initial repair at infancy. The simultaneous reconstruction of functional nasal and labial muscles dictate the growth and development of the underlying facial skeleton as well as the appearance of the lip and nose.[1,2] The aesthetic form of the lip is the result of both a carefully designed skin incision and the muscle repair at the initial surgery. Paramount to the normal appearance of this central region of the face is the nasal repair. The nose is at least as important as the lip in terms of overall appearance and perhaps more so in terms of its implications of future surgery. More specifically, the position of the ala as well as the nasal sill is quite difficult to manage in revision surgery, especially when the cartilage growth has been distorted and magnified over many years. Nostril symmetry and good form of the rim are important to achieve as well.

Of the multiple skin incisions that have been used, the geometric triangular and quadrangular incisions violate the subunits of the upper lip (with the exception of the more recently described anatomic subunit repair), whilst the advancement rotation and its modifications more accurately replicate normal anatomic structures.[3–5] Furthermore, disadvantages of most geometric designs include the tendency to create a long lip with incisions that cross the philtral column and can be difficult to correct secondarily, with conversion to a more anatomically appropriate skin incision impossible if eventual revision is required.

As the habilitation of cleft lip and palate consists of a series of procedures whose timing is dependent on chronological and developmental milestones throughout life, the initial lip/nose repair, which is often the first of many interventions, sets the tone for all procedures that follow it. It is also important to keep in mind that the staged reconstruction of these patients is a stepwise process and that careful consideration must be given to each procedure and its downstream effects on growth and blood supply such that 'bridges' are built and not burned. Whilst the construction of the labial and nasal muscular rings guides the eventual appearance and symmetry of the lip and nose, the individual's innate ability to heal and scarring tendencies also play a key role in the aesthetic appearance of the repair.[1,2] Certain technical shortcomings in the repair can also lead to less than optimal results, as can infection, inadequate nutrition and poor post-operative care.

The underlying skeletal platform must be considered when planning a lip revision, as the presence or absence of a bony alveolar cleft or maxillary hypoplasia also greatly impacts the appearance of the nasolabial structures as the child grows. When the ala is left behind in the initial surgery, regardless of attempted soft-tissue correction and camouflaging techniques, facial harmony can only be accomplished when the hard tissue problems have been addressed. Therefore, it is recommended that depending on the age of the child and the degree of skeletal dysplasia, major soft-tissue revisions be deferred until bone grafting or LeFort osteotomy has been accomplished when possible. This is, of course, guided by the psychosocial status of the patient as well as the magnitude of the secondary deformity.

When trying to determine whether a minor revision or a complete takedown of the lip is required, an understanding of the initial deformity and the goals of primary surgery are important. Understanding the secondary deformity and its global functional and aesthetic shortcomings are also crucial. Lesser procedures, transpositions and simple scar revisions can be used to address minor height mismatches of the white roll, vermilion notching or vermilion fullness when the muscle is otherwise noted to be functional and united across the cleft. If applied inappropriately, however, these 'minor' procedures might only serve to amplify the deformity, increase scarring or leave the patient well short of a complete correction. A complete takedown of the lip should be considered if there are significant issues with lip height or symmetry, nasal symmetry, substantial vermilion/white roll mismatches or a dehiscent orbicularis oris. Lastly, when there is significant damage and scarring to the cleft adjacent tissue, especially in the case of the bilateral cleft lip, one may have to recruit nearby tissue to reconstitute the philtral complex and reconstruct the muscular ring.

Re-opening the lip may also be advantageous in that it provides an excellent opportunity and additional access to address residual nasal and septal deformities or turbinate issues. Whilst nasal revision is often times simply an extension of lip revision surgery, it will be covered in detail in another chapter of this book.

Note on sutures: Unless otherwise specified, the author uses 4-0 chromic gut or polyglactin on tapered needles for mucosal closure, 4-0 polyglactin or polydioxanone for muscle approximation, 5-0 or 6-0 polyglactin or poliglecaprone on cosmetic cutting needles for deep dermal facial sutures and 5-0 or 6-0 nylon or fast gut on cosmetic cutting needles for skin. Suture selection depends somewhat on the age and size of the patient.

CUTANEOUS LIP PROBLEMS

Long upper lip

The long upper lip is infrequently seen with the predominance of advancement rotation repairs performed today. Excessive lip length was primarily a problem of the triangular and quadrangular repairs, but can be encountered as the result of a long lateral lip incision with overzealous rotation in an advancement rotation. The long lip can be a difficult problem to correct as the muscle and skin have accommodated and grown over time, frequently requiring the horizontal excision of tissue at the supravermilion level or in the subalar region. The scars left by these revisions, though reasonably well camouflaged by the white roll and the alar crease, respectively, are less than optimal in appearance. If lip fullness is encountered in the vermilion region as an isolated problem with the cutaneous lip appropriately symmetric, care must be taken with the orientation of the excision so as not to lengthen the incision in the wrong plane whilst removing volume. To remove an isolated bulge in the vermilion, a T-shaped excision can be effective, with the bulk of tissue transversely excised from the wet mucosa and closed inwardly towards the oral cavity.

REDUCTION OF LIP HEIGHT

Subalar excisions or supravermilion excisions can be used to adjust the height of a lip when excessive lip length is encountered. Either form of excision can be combined with philtral modifications, and both generally require the removal of skin, muscle and possibly mucosa. Both the subalar and the supravermilion excisions can be designed symmetrically or asymmetrically to address specific length issues (Figures 68.1).

Tight upper lip

The tight upper lip can stem from overly aggressive soft-tissue excision at the time of primary or secondary repair or be the result of a protuberant premaxilla. The appearance of tissue deficiency can be further accentuated by maxillary hypoplasia or a full lower lip. Further lip revision that includes soft-tissue excision might only serve to enhance the problem unless distant tissue is recruited

in the form of an Abbé flap. This pedicled cross lip flap, based on the labial artery, will add width and appropriate bulk, whilst decreasing the width differential between the upper and lower lip. The Abbé flap may also be of value when the prolabial tissue has been severely damaged by scar. One must take care, however, to keep the philtrum reconstruction within the normal range of philtrum width.

RECRUITMENT OF DISTANT TISSUE

When the philtral region has been destroyed by scar or when there is a significant full-thickness tissue deficiency, a pedicled Abbé flap or lip switch flap is designed based on the labial arterial pedicle of the lower lip. The flap as well as the inset defect can be customized based on the recipient site requirements for height and aesthetics (Figure 68.2).[6]

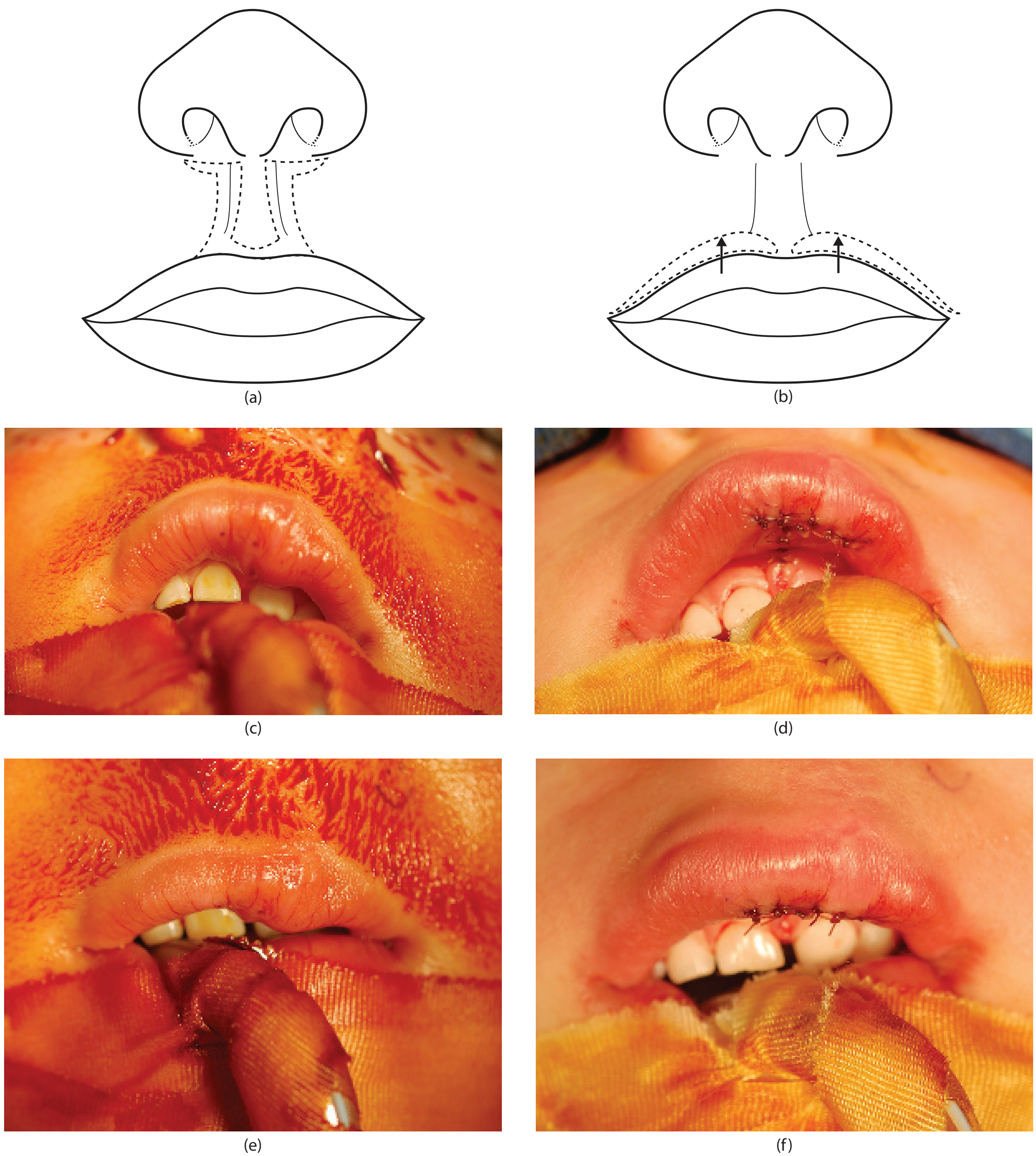


Figure 68.1 (a and b) Reduction of lip height. (c–f) Mucosal bulge of the red lip amenable to a T-shaped excision of the wet mucosa. This will prevent visible scarring, by keeping the incision at the wet-dry line and extending inward.

- The upper lip incision can be designed to allow downward rotation of the lateral lip elements ('Y' shaped – Figure 68.2a through c) or it can involve a full-thickness excision (Figure 68.2d through g) of damaged /scarred tissue.
- A full thickness shield, 'W' or rectangular-shaped flap is designed in the lower lip, including skin, vermilion and mucosa.
- One side of the flap remains pedicled at the vermilion, based on the labial artery.
- The flap is rotated 180°.
- Inset is accomplished is accomplished by a three layer closure (mucosa, followed by muscle and skin).
- The pedicle is divided after 14 days and the remainder of the flap is trimmed and inset (Figure 68.2h).

Short upper lip

The short upper lip may be the result of several different shortcomings in the primary lip repair. Most commonly, it is the result of an under rotated, improperly/incompletely repaired or dehiscent muscle and this will require a re-repair of the lip. In this case, the original repair scar can be used to access the nasal and labial muscles for an exacting functional repair. If conversion to an advancement rotation from a geometric repair is feasible, it should be considered, as this places the cutaneous scars in a more natural position. Vertical scar contracture might also play a role in the short lip and can be broken up by small z-plasties in the cutaneous and vermilion lip. When the muscle is found to be intact and is dynamically symmetric and the height discrepancy or contracture involves only one aspect of the lip, such as the vermilion or the vermilion–cutaneous junction, this can sometimes be corrected with a more limited cutaneous or musculocutaneous revision.

MINOR NOTCHING OF THE VERMILION

Vermilion Z-plasty: Vermilion muscle flaps are created at the site of the notch and transposed to fill the vermilion defect. Once the flaps are raised, they can be transposed with skin hooks and the incisions then more specifically extended or trimmed to fill the given defect.

Vermilion V-Y plasty: A V-shaped musculomucosal incision is created approaching the vermilion notch with the apex of the 'V' pointing towards the maxillary vestibule. The

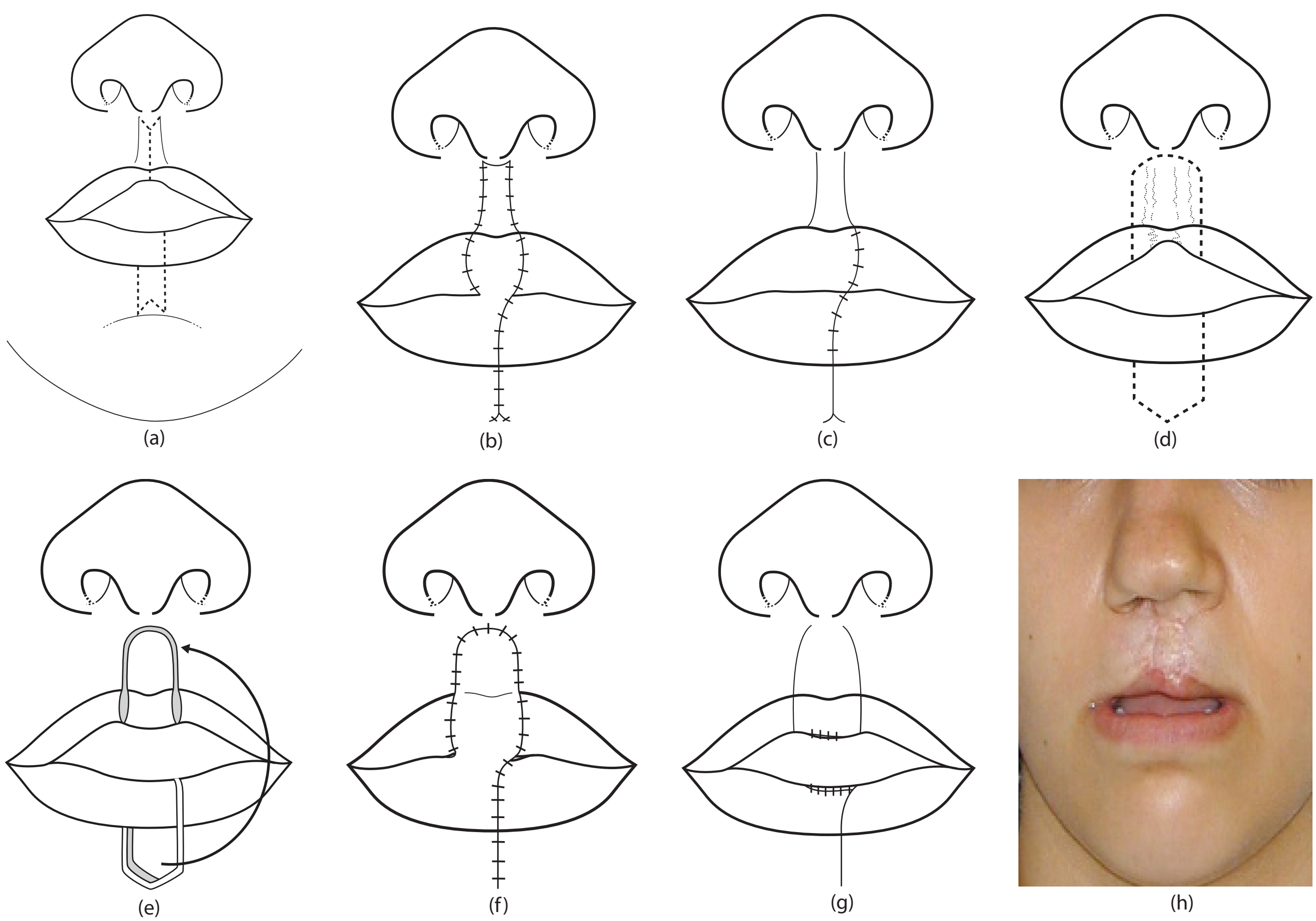


Figure 68.2 (a–g) Recruitment of distant tissue. (h) Mutilated upper lip. This patient could benefit from an Abbé transpositional flap.

incision is then closed as a Y, advancing the leading edge of the incision into the notch (Figure 68.3).

ASYMMETRIES AND/OR WHITE ROLL MISALIGNMENT

Wavy line excision: A wavy line excision of an unaesthetic scar can be used to create symmetry of the Cupid's bow when it is peaked and there is otherwise no notch of the lip. This is based on Pfeiffer's wavy line lip closure, where the wavy line helps to lengthen the skin of the lip along the philtral column (Figure 68.4).[7]

Diamond excision: Similar to the wavy line, a diamond-shaped excision can be used to eliminate white roll misalignment and Cupid's bow asymmetry, based on its geometry and ability to lengthen (Figure 68.5).

Z-plasty: When the defect simply involves a white roll misalignment, a simple z-plasty can be performed (Figure 68.6).

Complete revision: The cleft deformity is re-created and a complete muscular reconstruction and cutaneous revision is accomplished. Anatomic points are marked as they would be for a primary lip repair.

Unilateral cleft: The skin is marked similar to that of a primary repair, and for this, I favour Delaire's markings with a functional muscular repair (Figure 68.7a).[3]

A – Superior internal angle of the non-cleft nostril
A' – Superior internal angle of the cleft nostril
B – The base of the non-cleft columella
C – The depth of Cupid's bow
D – The non-cleft peak of Cupid's bow
1 – Point marks base of the columella on the cleft side (A–A'–1–B should form a parallelogram)
2 – Point from B–1 extended to the best skin adjacent to the scar (separates nasal skin from lip skin)
3 – Point should equal D–C (or slightly less, as white roll permits) and will create the peak of Cupid's bow
4 – Point at the wet–dry line cleft side (roughly perpendicular from C–3)
5 – Point at the junction of alar base and lip
6 – Point on the cleft side skin adjacent to the scar, where a line from 5–6 separates nasal skin from lip skin
7 – Point marks the best/thickest white roll on the cleft side
8 – Point at the wet–dry line perpendicular to line drawn from 7, coincides with widest portion of dry vermilion

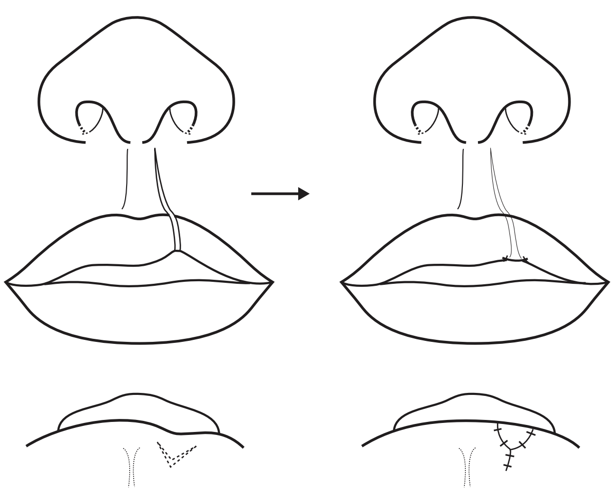


Figure 68.3 Vermilion V–Y plasty.

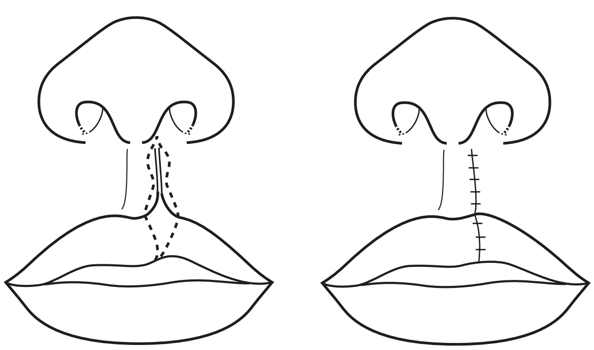


Figure 68.4 Wavy line excision.

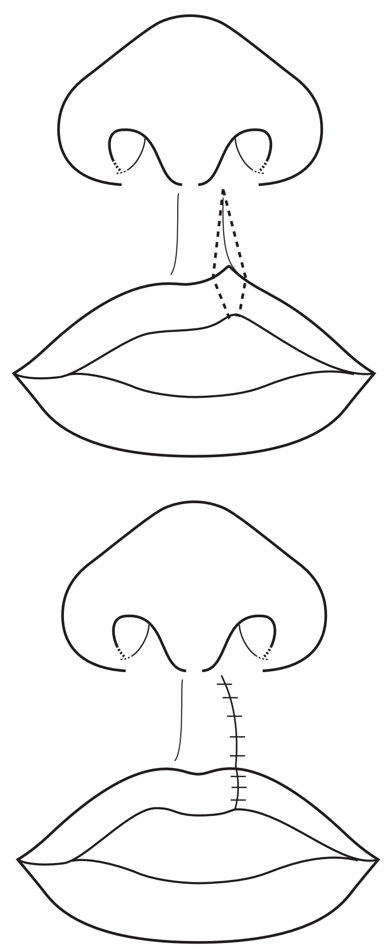


Figure 68.5 Diamond excision.

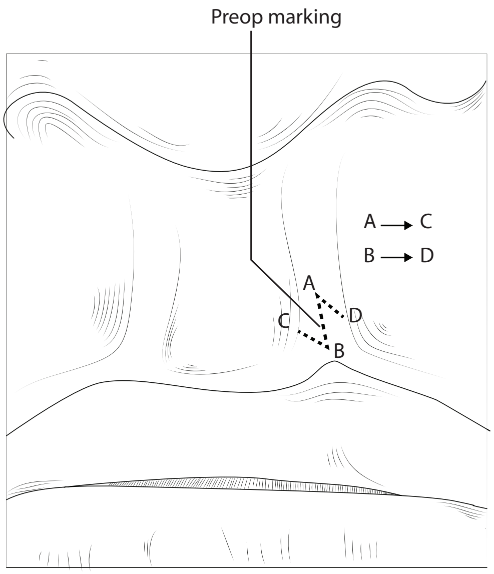
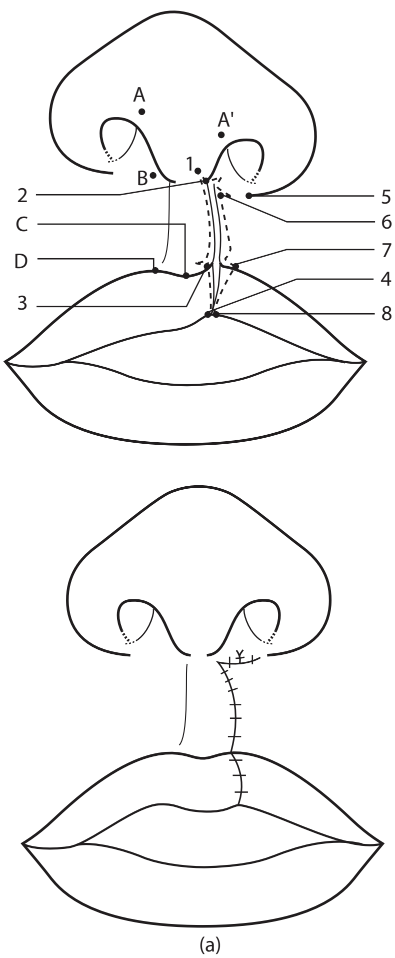


Figure 68.6 Z-plasty.



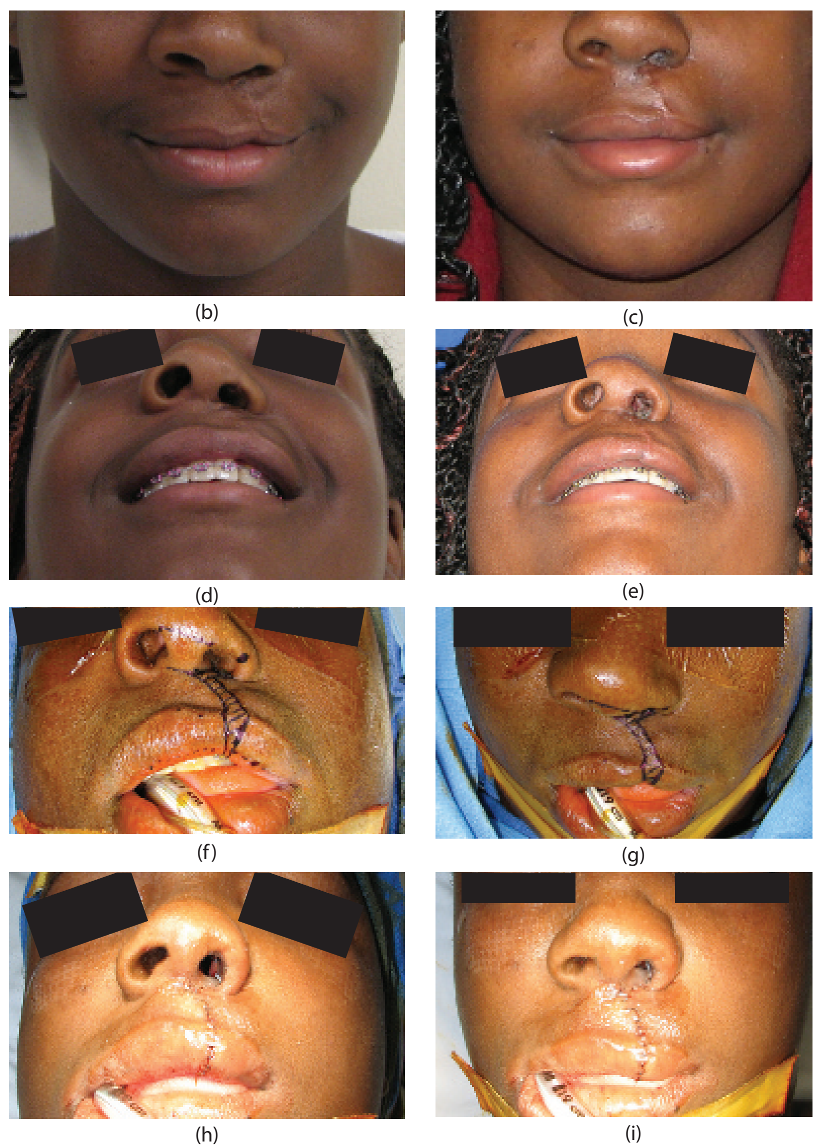


Figure 68.7 (a) Unilateral cleft. (b–i) Girl with left UCLP. She has an incomplete muscle repair, mild notching, a widened left Cupid's bow point and a depressed left alar base. She underwent total lip revision without rhinoplasty.

Additional length in the repair can be obtained through the use of a wavy line as the incision approaches the mucocutaneous junction or by creating a small triangular flap from the non-cleft side to be inserted above the white roll. This should enable 1–3 to equal B–D in length.

Careful attention is given to dissecting and reconstructing the transverse nasalis and the orbicularis oris muscles at the cleft edges. Care should be taken to minimally undermine the muscle on the non-cleft side so as not to efface the philtral dimple. Wide subperiosteal undermining of the anterior maxilla, anterior zygoma and cleft side perinasal bone should be utilized as needed to facilitate advancement. Periosteal scoring can also be utilized as needed.

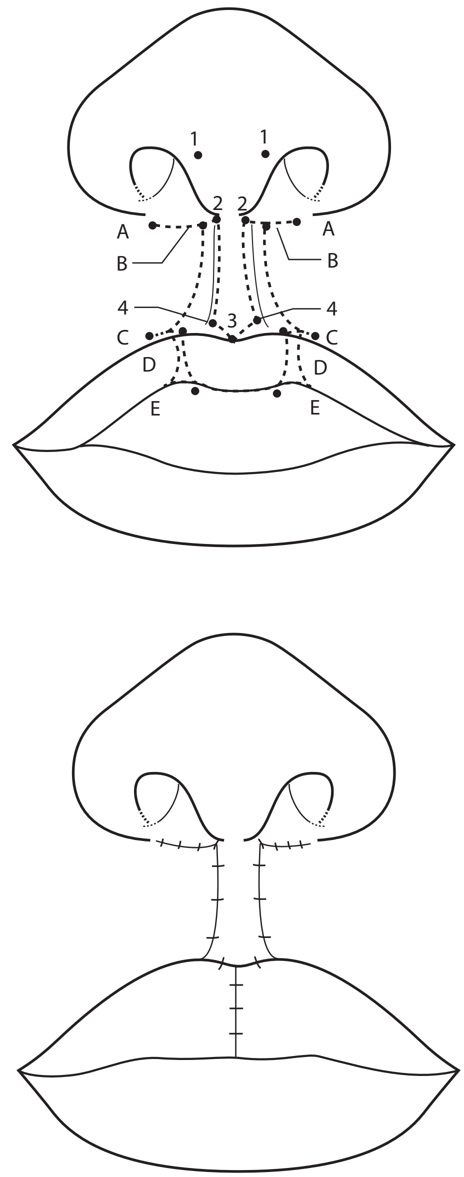
Bilateral cleft: The skin is marked similar to that of a primary repair, and for this, I favour a modification of Delaire's skin markings with functional muscular repair (Figure 68.8a).[3]

A – The junction of the alar base and lip
B – Lip point lateral to the philtrum scar that will be used to create new philtrum. Line from A–B delineates the nasal skin from the lip skin
C – The extent of the back cut (C–D) superior to and including the best/thickest white roll (D); also lateral contribution to the peak of Cupid's bow
D – Point marks the best/thickest white roll; also the lateral contribution to the depth of Cupid's bow
E – Marks the greatest width of wet-dry line, perpendicular from line D (these turndown flaps, C–D–E, form the lateral lip that will be used to reconstruct the central vermilion)
1 – Point marks the superior internal angle of the nostril
2 – The base of the columella
3 – The depth of Cupid's bow
4 – Point marks the medial contribution to the peak of Cupid's bow (3–4 is straight or slightly concave)

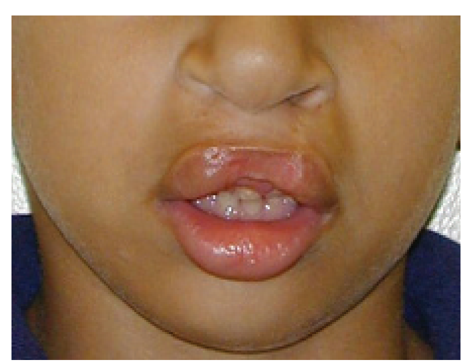
The muscular reconstruction, like the vermilion, is accomplished via the lateral nasolabial elements. Again, wide subperiosteal undermining and/or periosteal scoring can be used as needed to facilitate this process (Figure 68.8b).

PHILTRUM PROBLEMS

Obliteration of the philtral dimple and Cupid's bow asymmetries are occasionally seen following primary lip repair. A flat Cupid's bow is sometimes the result of a triangular repair. The philtral dimple can often be preserved in unilateral clefts with minimal cutaneous undermining of the non-cleft side at the time of initial repair. A natural dimple is difficult to restore secondarily. Additionally, widening of the scar in the philtral column position can occur as a result of early wound tension, poor suturing, patient factors or wound breakdown at the initial repair. This can often be treated with simple excision and



(a)



(b)

Figure 68.8 (a) Bilateral cleft. (b) Boy with an excessively wide philtrum and a poor mucosa match of the central lip. This will require a complete lip revision with alar repositioning.

augmented with other surface treatments such as CO_2 laser or dermabrasion.

The philtral column(s) is/are also often left flat. This is largely due to the fact that we cannot surgically re-create the dermal insertions of the orbicularis muscle. We are therefore left to provide surgical camouflage, with carefully everted skin edges, dermal grafts/flaps or muscular closure techniques to augment this area.

CUTANEOUS DEFECTS

Isolated unaesthetic cutaneous lip scarring can be managed similar to other facial scars, by excision, dermabrasion etc. One must keep in mind the orientation of the philtral column and other local lip structures. For instance, the horizontal orientation of a running w-plasty might not suit this area as well as a wavy line excision to re-create the linear philtral column. One must also be mindful that the skin of the nose and the skin of the lip are of different quality and contain different adnexa, much as the skin of the cutaneous and red lip. If the skin of the nose has bled down onto the skin of the upper lip or conversely, the skin of the vermilion has bled into the cutaneous lip, this must be addressed in the revision.

SECONDARY CLEFT PALATE SURGERY

Speech and transverse growth are the primary outcome measures of cleft palate surgery. Both are highly dependent on the type and timing of the initial repair. Despite appropriate interventions at the correct time, maxillary hypoplasia, velopharyngeal dysfunction (VPD) and oronasal fistulae can occur. In order to identify patients in need of revision surgery, they should be followed and evaluated by an interdisciplinary team that will provide interval palatal evaluations, dental care, orthodontic care, hearing evaluations and speech evaluations. For purposes of this chapter, the discussion is limited to VPD and oronasal fistulae.

ORONASAL FISTULAE

Oronasal fistulae have been reported with a wide range of occurrence. They are frequently left intentionally at the alveolus, to be repaired at the time of secondary bone grafting. They can, however, occur anywhere on the palate and frequently occur in the middle of the palate at the hard palate–soft-palate junction. The failure rate of fistula repair increases with each unsuccessful attempt at revision. Many techniques have been described, including the application of local flaps (palatal re-repair), tongue flaps, pedicled flaps, free tissue transfer and augmentation with acellular dermis.[8,9]

Midpalatal and junctional fistula repair

The palatal re-repair, raising the original hard palatal flaps and if necessary performing a functional revision of the soft palate, is most useful in most circumstances (Figure 68.9). For large fistulae, acellular dermis can be useful as an additional layer and might facilitate healing in the eventuality of dehiscence.

- Incisions are made in the mucosa around the fistula and it is turned in towards the nasal side to allow creation of a nasal layer (wound edges everted and sutures tied to nasal side).
- A two-flap or von Langenbeck palatoplasty is performed on the remaining hard palate mucosa, scoring or release is performed laterally and around the neurovascular bundle as needed.
- Acellular dermis can be interposed and secured between the oral and nasal flaps as needed.
- The flaps are sutured in the midline (Figure 68.9e through h).

Velopharyngeal dysfunction

Continuous perceptual speech evaluation is the primary tool for evaluating VPD. The longitudinal evaluation of

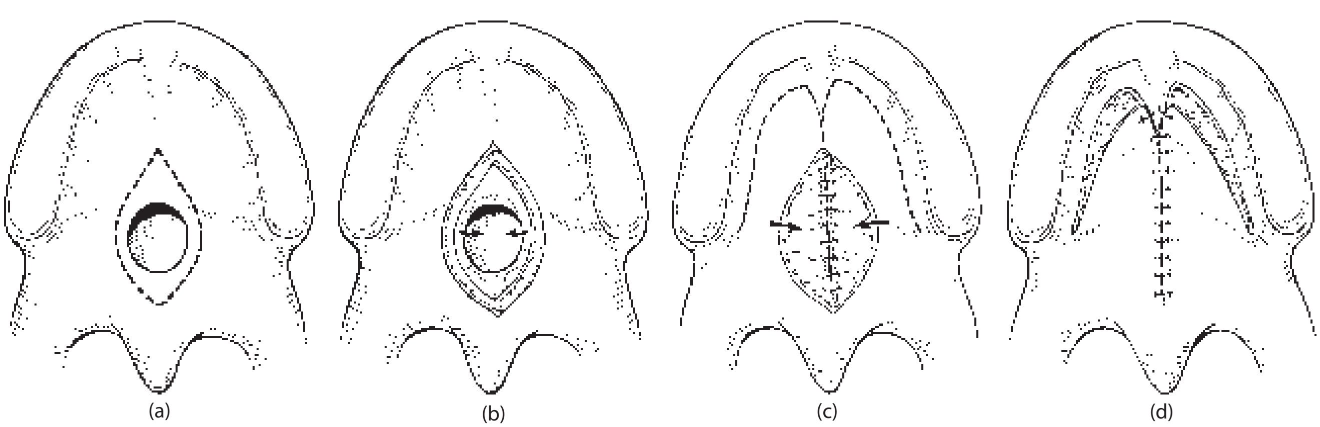
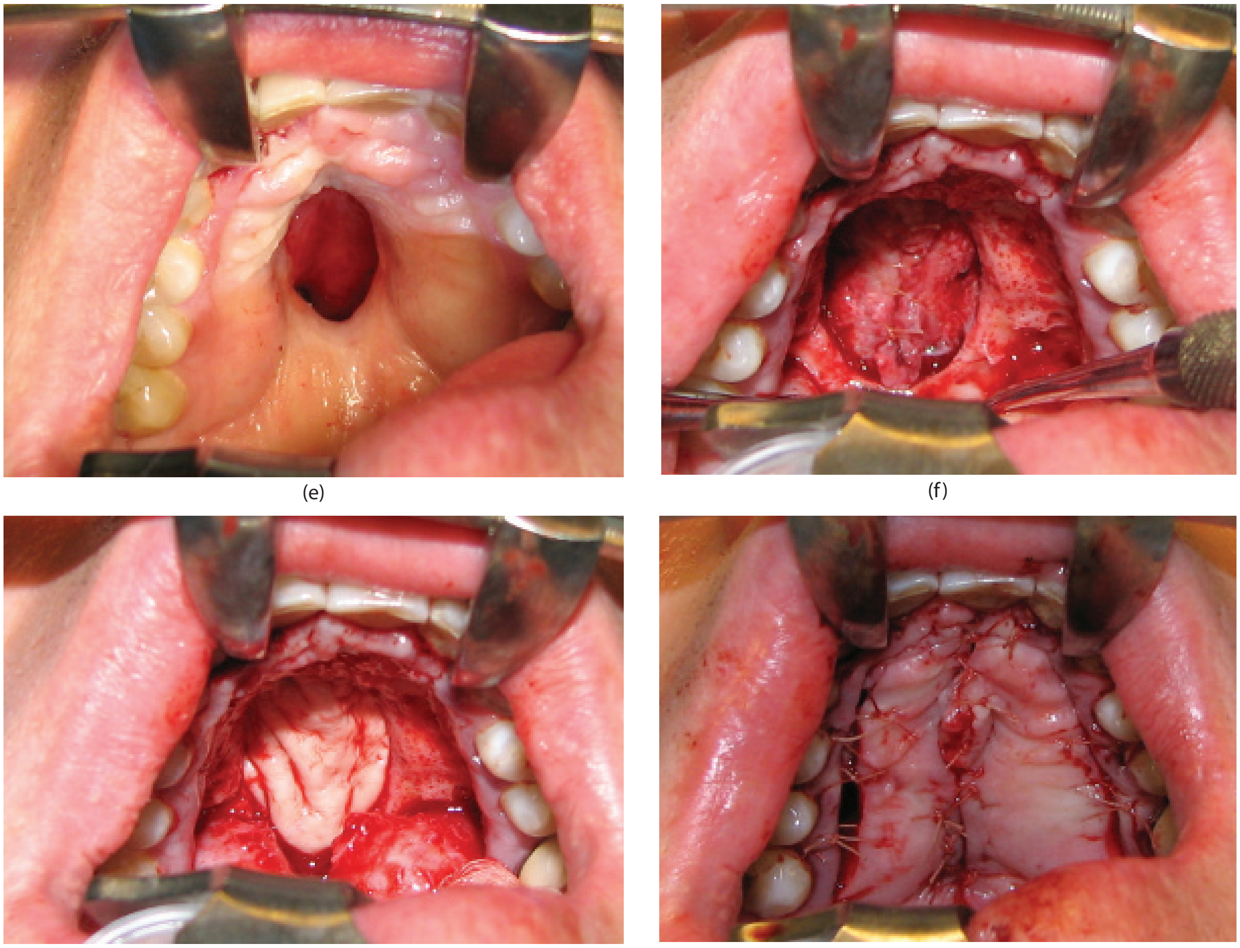


Figure 68.9 (a–d) Midpalatal and junctional fistula repair. (*Continued*)



(e)

(f)

(g)

(h)

Figure 68.9 (e–h) Hard palate cleft fistula closed with an interpositional layer of allogenic dermal graft.

speech intelligibility can begin shortly after palate repair. Early identification and correction of VPD is critical to avoid the development of compensatory misarticulations. Characteristics of VPD include hypernasal resonance, nasal escape, nasal turbulence and inadequate intraoral air pressure.[10] In addition to perceptual speech evaluation, videofluoroscopy, nasal endoscopy and nasometry might be useful in identifying the size and nature of the velopharyngeal defect.

Surgical treatment largely consists of three modalities: revision palatoplasty, superiorly based pharyngeal flap and sphincter pharyngoplasty.

Revision palatoplasty

Revision palatoplasty in an effort to avoid the morbidity of pharyngoplasty is an attempt to restore functional continuity to the palatal muscles and length to the palate, especially in patients who have had little to no dissection of the velar muscles. In essence, this represents an intravelar veloplasty where one has not been previously performed. Palatal re-repair, if effective for speech, can avoid the sequelae of some pharyngoplasty techniques, such as turbulent or disordered night-time breathing and mucus trapping. In this group, the velar muscle bundles are seen to be oriented sagitally (Figure 68.10), instead of transversely as one might see in a submucous cleft palate. Techniques described for this purpose include radical intravelar veloplasty with retropositioning of the muscle sling as described by Sommerlad or the Furlow palatoplasty.[11–13] Both achieve retropositioning of the velar sling and have demonstrated efficacy in limited cohorts. These revision procedures are felt to be more physiologic than pharyngoplasty and are best utilized for those who demonstrate small to moderate antero-posterior gaps as viewed by nasoendoscopy or videofluoroscopy. Should VPD persist following 6–12 months of additional speech therapy, pharyngoplasty is still an option.

Superiorly based pharyngeal flap and sphincter pharyngoplasty

Both the pharyngeal flap and the sphincter pharyngoplasty have demonstrated value in the management of VPD, but more than the type of procedure selected or the orientation of the gap, the velopharyngeal gap size is most likely to influence the clinical outcome of the operation.

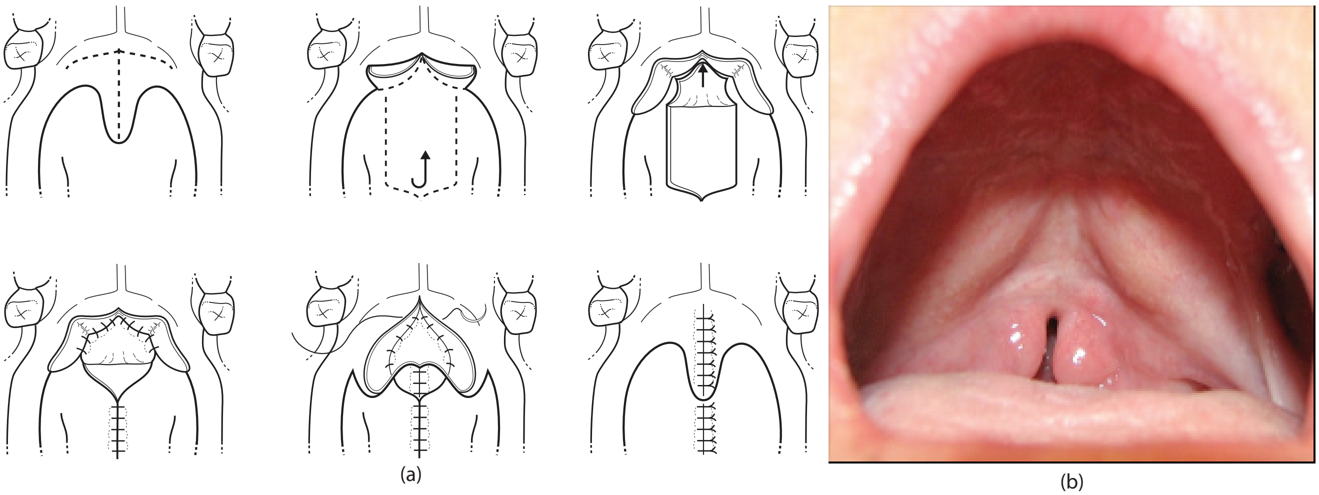


Figure 68.10 (a) Superiorly base pharyngeal flap. (b) Sagittal position of the cleft muscle bundle in a submucous cleft. This is amenable to an intravelar veloplasty procedure via Sommerlad's technique or a Furlow repair.

Despite multiple attempts in the literature to delineate the best operation for specific velopharyngeal defect orientations (coronal, sagittal etc.), recent randomized controlled comparisons of sphincter pharyngoplasty and pharyngeal flap for VPD demonstrated no difference in long-term speech outcomes between the two.[10,14] Therefore, one must consider specific patient issues and the potential morbidities of the operation when selecting a VPD revision technique. Videofluoroscopy or nasoendoscopy can be used to choose the point of placement of the sphincter or estimate the size of the pharyngeal flap to maximize its effectiveness.

Superiorly based pharyngeal flap

- The palate is divided in the midline a few millimetres from the hard palate through the uvula. Lateral incisions (nasal flaps) are made anteriorly and extended towards the pharyngeal walls.
- A superiorly based flap is elevated at the depth of the prevertebral fascia approximately two-third the width of the posterior pharyngeal wall, long enough to reach the anterior extent of the palatal incision without tension.
- The tip of the flap is inset into the apex of the palatal incision, the lateral aspect of the flap is sutured to the lateral edges of the soft-palate flaps.
- The nasal flaps are closed over the raw surface of the pharyngeal flap.
- The palate is closed in the midline (Figure 68.10).

Modified hynes sphincter pharyngoplasty[15]

- The palate is retracted superiorly with an instrument or by a suction catheter passed through the nose and sewn to the palate (Figure 68.11).
- Vertical incisions are made along the anterior aspect of the posterior tonsillar pillars in a cephalo-caudad direction.
- A similar incision is made on the posterior aspect of the tonsillar pillars, capturing the palatopharyngeus muscle in a superiorly based flap.
- The flaps are transected as low as possible to allow tension free apposition.
- The superior aspect of the posterior tonsillar incisions is joined transversely across the posterior pharynx at the depth of the prevertebral fascia.
- The pillar flaps are transposed and sutured end to end (Figure 68.11c) or in an overlapping fashion (Figure 68.11d) (to decrease the port size).

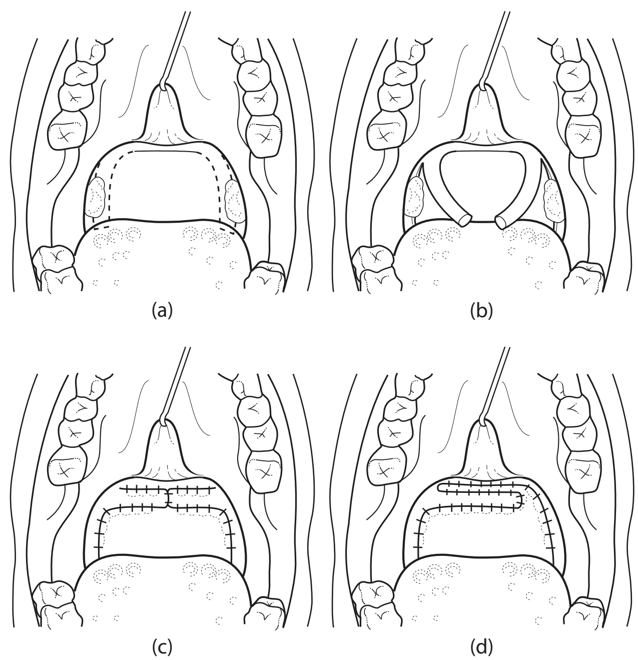


Figure 68.11 (a–d) Modified Hynes sphincter pharyngoplasty.

- The superior and inferior transverse incisions are closed.
- The tonsillar pillar defect is closed.

Top tips

- Consider the totality of the lip/nose defect as this frequently leads to and is best served by total lip revision and muscular reconstruction.
- The lip and nose are sometimes best addressed in separate revision procedures as many alar base problems are more readily addressed with the lip revision. Once this is allowed to heal, a more predictable foundation for definitive reconstructive rhinoplasty exists.
- Consider revision palatal surgery for small to moderate velopharyngeal gaps when an intravelar veloplasty has not been previously performed; it is a more physiologic option than pharyngoplasty. If a subsequent pharyngoplasty is required, perhaps a less obstructive one can then be done.
- The first opportunity to close a palatal fistula is the best one; do not limit your results by performing less surgery than is required. Consider augmenting the closure with acellular dermis when appropriate.

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69

Alveolar bone grafting in cleft patients

CONTENTS

PERSPECTIVE I

SERRYTH COLBERT and ADRIAN SUGAR

All surgery in children and adults with clefts of the lip and/or palate aims to reconstruct in so far as it is possible normal anatomy and function. The evolution of lip and palate repair demonstrates this well. Consequently, cleft surgeons anticipated the need to repair the alveolar cleft long before it was possible to achieve clinically. It was even recognized that repair should involve separate nasal and oral layers. Current clinical practice has focused on what is usually referred to as 'secondary' alveolar bone grafting (ABG), referring to the placement of a graft at the time of eruption of the secondary dentition and specifically shortly before the eruption of the permanent maxillary canine tooth on the cleft side. The term 'secondary alveolar cleft bone grafting' is actually anomalous as this is a primary cleft operation. The child, for example, with a unilateral complete cleft of the lip and palate will require three primary operations: lip, palate and alveolus repair.

Historically, several surgeons have carried out 'primary' alveolar cleft bone grafting sometimes using autogenous rib as the donor material. Timing has varied between 6 months of age, at the same time as lip and palate repair up to 3–4 years but always in the time of the 'primary' dentition. The literature demonstrates good initial results but with later concerns. Mainly, these relate to the impact on maxillary growth but also that the alveolar bone later often becomes deficient, too deficient to allow normal eruption and orthodontics of the permanent dentition and therefore further bone grafting is required.

In recent years, there also been renewed interest in the use of periosteoplasty to achieve the same end. Although good results have been demonstrated, these have not often been replicated in other units. Interest has also been generated in the use of bone promoting products such as bone morphogenic protein and some good results have been reported. However, in most studies reported, BMP has been combined with harvested autogenous bone which rather defeats the purpose of avoiding a donor site. It also seems to be critical, how it is prepared and used and it is also very expensive.

Secondary ABG is generally carried out in the age group 8–11 years depending on the skeletal and dental development of the child. The most commonly used technique is essentially that described by Boyne and Sands in 1972[1] and popularized by the publication of a large series of excellent results by Abyholm, Bergland and Semb in 1981.[2]

Aims of alveolar cleft bone grafting

The primary aim of alveolar cleft bone grafting is to create a continuous maxillary alveolus and thus the maxilla as a single bony structure. The detailed aims are

- To repair oro-nasal fistulae and thus prevent food and fluids coming out of the nose, avoid a persistent discharge from the nose, and improve speech
- By repairing fistulae, allow the patient to build up intra-oral pressure and thus enable them to perform such commonplace activities as blowing up balloons and sucking on a straw
- To provide bone support to teeth adjacent to the alveolar cleft defect
- To allow the eruption of permanent teeth especially the canine tooth on the cleft side

- To permit the movement of teeth by orthodontics and create an intact dental arch
- To give support to restorations (implant, bridge or denture) in such cases where there are missing teeth and it is not possible to create an intact dental arch
- To provide support for the alar base of the nose, the lip and columella
- To stabilize the premaxilla in bilateral cases
- By creating a one piece maxilla, to enable if necessary later advance of the maxilla by osteotomy in one piece

Assessment for alveolar cleft bone grafting

When planning ABGs, the cleft surgeon should always see the patient with the cleft orthodontist. In our unit, we aimed to do this at 8 years of age and we reported our ABG results in an audit of all cases carried out between 1996 and 2000 measuring the result of an oblique occlusal radiograph taken 6 months post-operatively (Table 69.1). The scale used was after Bergland et al. in 1982 and modified to measure against the adjacent permanent erupted tooth, usually a central incisor, as the permanent canine of course would not normally be erupted at this time in most cases. In this way, only alveolar bone height measured as 75% of normal or better (Types 1 and 2) with no other deficiencies are regarded as good.

Table 69.1 ABG outcomes in South Wales (1996 – 2000)

Unilaterals and bilaterals all cases (*n* = 110)	
Type 1	86%
Type 2	8%
Type 3	2%
Failure	4%
Unilaterals results overall (*n* = 80)	
Type 1	71 (88%)
Type 2	6 (8%)
Type 3	2 (3%)
Failure	1 (1%)
Bilaterals results overall (*n* = 30)	
Type 1	24 (80%)
Type 2	3 (10%)
Type 3	Nil
Failure	3 (10%)
Unilaterals late and adults (*n* = 19)	
Type 1	12 (63%)
Type 2	4 (21%)
Type 3	2 (11%)
Failure	1 (5%)
Unilaterals early cases only (*n* = 61)	
Type 1	59 (97%)
Type 2	2 (3%)
Type 3	Nil
Failure	Nil

Notes: Late = after the eruption of the maxillary permanent canine tooth on the cleft side; Early = before the eruption of the maxillary permanent canine tooth on the cleft side.

- Although the results of this audit showed generally good results, we noted two negative findings. Patients grafted late (after the eruption of the permanent canine tooth) and those having bilateral ABGs generally did less well. We also noted that late grafting was often associated with delays caused by prolonged orthodontic preparation or lack of compliance with orthodontic preparation. As a result and for some years, we assess these patients at 7 years of age and thus graft them earlier. This has produced some different and generally improved outcomes.
- The minimum pre-operative imaging required is an OPT and an oblique occlusal radiograph. When the presence or condition of both erupted and unerupted teeth is not clear or when the presence of a relevant alveolar defect is not clear, a cone beam CT is obtained. By 'relevant' alveolar defect, we mean one which if not grafted will prevent the normal eruption of permanent teeth and/or subsequent orthodontic movement of those teeth. Decisions about timing of surgery, about the need for orthodontic expansion, for stabilization of the premaxilla and for tooth extraction at the time of ABG are made jointly.

Operating technique

- The criteria required at the alveolar defect site are a good blood supply, restoration of normal anatomy especially of the nasal floor at the correct height, elimination of excess tissue (usually scar tissue) within the alveolar defect and complete cover of the graft by soft tissue.
- For a good blood supply, the recipient site should ideally be free of scars which situation only really exists in a surgically unoperated cleft. Delayed closure of the alveolar cleft after previous repair of the lip and/or the hard palate certainly involves dissection in a scarred area. The graft should have close contact to surrounding tissues, which means to the alveolar processes as well as to the soft-tissue cover. Dead space around the grafted material will fill with haematoma, which through its organization by connective tissue leads to a thicker scar and so should be avoided.
- Complete coverage of the graft by soft tissue is an important factor for achieving a good blood supply and is essential for the protection of the graft against infection. The blood supply of mucoperiosteal flaps raised in children below the age of 12 years appears to have very good viability especially compared to that of adults. If infection occurs post-operatively, it will tend to produce necrosis of the flap, graft exposure and with it graft failure. The ideal

soft-tissue cover is that which corresponds completely to the normal anatomy of this area. The nasal mucosa should be horizontal (axial) without any transposed oral mucosa. The palatal mucosa should be adjacent to the alveolus at its palatal inclination, and the buccal mucosa should similarly lie on the inclination of the buccal alveolus. Over the alveolar crest, there should be fixed gingivae which are a requirement for the unerupted teeth to erupt, with mobile mucosa away from the crest.

DONOR SITES

- A wide variety of materials has been proposed for alveolar grafting including homologous bone, allogeneic freeze-dried bone marrow, homologous cartilage and various bone substitutes as well as bone morphogenic protein. More or less, satisfactory results with these materials have been claimed. Similar encouraging reports have been made of the use of gingiva-periosteoplasty although with some deleterious effect on growth. There is widespread acceptance that autologous bone grafts have the lowest risk in primary healing and arguably give the best results. We will therefore limit ourselves to considering them only.
- Different donor sites for autologous bone grafts have been proposed and used including anterior and posterior iliac crest, rib, mandible, calvarium, tibia, periosteal flaps and periosteal grafts. The decision in favour of one or other of the different donor sites depends among other things on the age of the patient at operation, i.e. the quantity of cancellous bone available at the different donor sites in different ages, as well as the convenience for the surgeon and the patient of the various donor sites. In an ideal recipient site, one can obtain good results with every graft but the literature and our own experience shows that autologous cancellous bone is the most proven successful graft with which one can fill the defect completely. It allows vessels to grow into the graft from the recipient site and to transform the graft into the locally adapted bone in the easiest and most rapid way. Moreover, cancellous bone has the highest resistance against infection.

In patients older than 2 years of age, cancellous bone can be harvested from the iliac crest with the help of a trocar. The use of a trocar reduces the invasion of the donor site procedure and also reduces the pain at the donor site. However, the core graft obtained is compressed which can be a disadvantage in contrast to cancellous bone chips harvested openly from the iliac crest which can be packed into every nook and cranny of the alveolar defect and compressed into it. The iliac crest itself can be raised as an osteoplastic flap and cancellous bone chips harvested from inside the ilium and the lid replaced. The anterior crest is our site of choice because it provides adequate cancellous bone and can be harvested simultaneously to the cleft procedure. The keys to prevention of post-operative morbidity at this site are the avoidance of any muscle stripping in particular on the lateral aspect of the crest, as well as the use of a cannula inserted into the wound at surgery after the lid has been replaced and used to infuse long acting local analgesia on a few occasions during the first 24 hours after surgery.

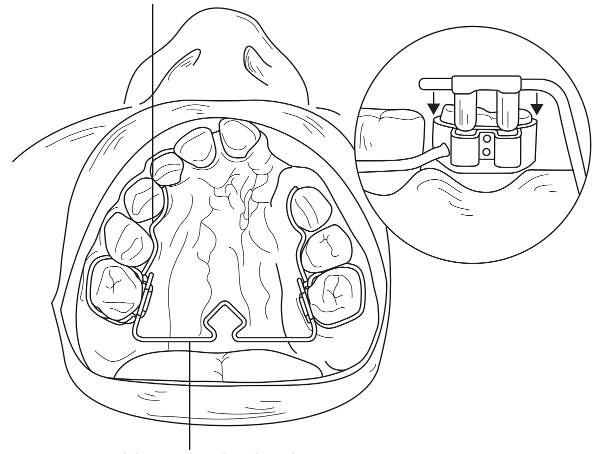


Figure 69.1 Removable transpalatal arch retention device.

Adequate stability of the premaxilla at and after ABG surgery is important in bilateral alveolar clefts in order to ensure good bony union between the fragments and across the clefts. If necessary, this can be achieved by a reasonably strong labial arch wire and orthodontic brackets/bands although when the premaxilla is reasonably stable this is not required. When arch expansion has been carried out before ABG, this can be retained during and after surgery by a posteriorly placed Trans-Palatal Arch (TPA). We have devised a removable TPA easily flicked out at the start of surgery giving the surgeon full access to the whole of the palate, and easily replaced at the end of the operation (Figure 69.1).

Rarely, the premaxilla is in a severely aberrant position and cannot be moved into an ideal position by orthodontics. In such cases, a premaxillary osteotomy can be carried out and we generally prefer to do that in conjunction with the bilateral ABG procedure.

Primary alveolar cleft bone grafting

The principal concerns about very early bone grafting have been the potential harmful effects on maxillary growth. However, a further concern is that while the early bone graft will often produce a good repair of the alveolar cleft, by the time the permanent dentition adjacent to the cleft is erupting (especially the permanent maxillary canine tooth) between 7 and 12 years of age +, commonly the bone in the alveolar cleft is of insufficient volume to support those erupting teeth and a further ABG procedure needs to be considered. The same criticism has been levelled at early periosteoplasty.

Secondary ABG

Our approach to ABG in South Wales (Morriston Hospital, Swansea and up to 1994, St Lawrence Hospital, Chepstow) has been essentially unchanged since 1985. Grafting has been carried out ideally in the mixed dentition shortly before the eruption of the permanent maxillary canine teeth.

All children with an alveolar cleft (classified with 'A' or 'a' on LAHSHAL) are seen on a multidisciplinary cleft clinic at least by the cleft surgeon and cleft orthodontist. This used to be at the age of 8 years but following the carrying out of an audit of all cleft ABGs carried out by the team between 1996 and 2000 (see Table 69.1), it was noted that the small number of poor results or failures were almost always in those children or young adults who were operated on a little late, sometimes because the orthodontic preparation started and finished too late. From this time, these children have been assessed at 7 years of age. In all cases, an OPT and an oblique occlusal radiograph of the alveolar cleft are taken (two occlusals in bilateral cases). Occasionally, when the position of ectopic teeth is difficult to determine or the size of the alveolar cleft too difficult to visualize, a cone beam CT scan is obtained. A decision is made on whether an ABG is required, whether any orthodontic preparation is necessary, when to proceed with the ABG, if any fistulae need to be repaired at the same time and if any dental extractions are required. It is rare to carry out other procedures simultaneously, except occasionally minor lip revision.

This approach also varies little from the method proposed by Boyne and Sands and reported by Abyholm and colleagues. When there has been any segment collapse present, the maxillary dental arch has been expanded orthodontically and in bilateral cases, the lateral segments and the premaxilla have been aligned. Following alignment, the expansion has generally been retained with a removable trans-palatal arch and lateral arms, and a labial arch wire in bilateral cases (Figure 69.2). However, in the last 10 years, the incidence of arch collapse has fallen quite dramatically and as a result pre-ABG orthodontic arch alignment has been required much less often.

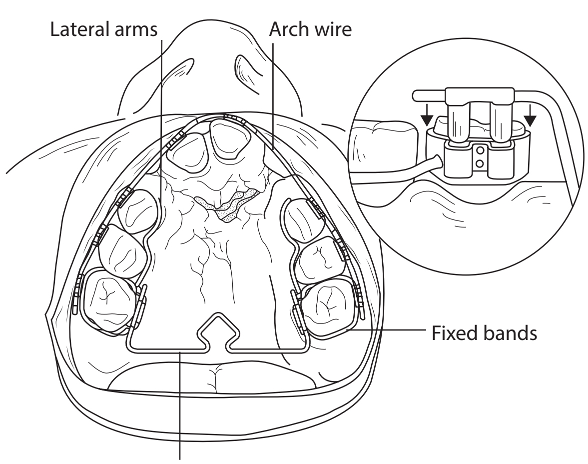


Figure 69.2 Maintenance of expansion with removable trans palatal archwire with lateral arms.

Only autogenous cancellous bone harvested from the anterior iliac crest has been used as the graft material and with consistently good results (Figure 69.3).

During the early part of this period, a significant number of cleft patients presented who had, for various reasons, missed the opportunity of receiving a graft into their alveolar clefts during the mixed dentition phase. In most cases, these have been managed with careful orthodontic preparation with fixed bands and tertiary ABG in the same surgical manager as described above. This has applied equally to those patients who have not required orthognathic surgery, the graft not only facilitating closure of fistulae but also giving support to dental restorations with or without osseointegrated implants. Such tertiary grafting can be very successful but in these older patients, the success rates are not as high as those in the younger children (Table 69.2).

The ABG surgical procedure starts with inspection of the hard and soft palate with a cleft gag in situ (the Dingman is ideal for these older children). If anterior palatal fistulae are present, these are generally repaired first in two layers if possible (Figures 69.4 through 69.6). The repair of any posterior palatal fistulae away from the alveolar cleft may be considered at this time.

The entire alveolar cleft is identified by the raising of labio-buccal muco-periosteal flaps after incising around any labial fistula (Figure 69.7). These flaps critically include keratinized gingivae. In unilateral cases, a flap is raised on the lesser segment from the alveolar cleft to the anterior aspect of the first molar tooth and a further smaller flap raised on the greater segment up to just across the midline. In bilateral cases, virtually no dissection is permitted on the premaxilla to preserve its blood supply. The flaps are raised separating oral from nasal mucosa.

The nasal layers are then identified and separated sharply from the palatal mucosa. Scar tissue and any excess nasal mucosa within the alveolar cleft are excised and the nasal floor repaired. It is important that this repair is carried out in such a way that the nasal floor lies at the same height as the normal side. Occasionally, a large inferior turbinate will obstruct an appropriately high

Table 69.2 Typical sequence of surgery for a unilateral ABG.

1) Inspection of the hard and soft palate and repair of any palatal fistulae present
2) Raising of labio-buccal muco-periosteal flaps around any labial sinus/fistula/scar
3) Separation of oral and nasal mucosa
4) Excision of any labial sinus present along with scar tissue and excess nasal mucosa within the alveolar cleft
5) Removal of erupted and buried teeth as planned
6) Repair of nasal mucosa at level of normal nasal floor
7) Harvest of cancellous bone from anterior iliac crest
8) Insertion of graft into alveolar defect
9) Flap advancement and closure over graft

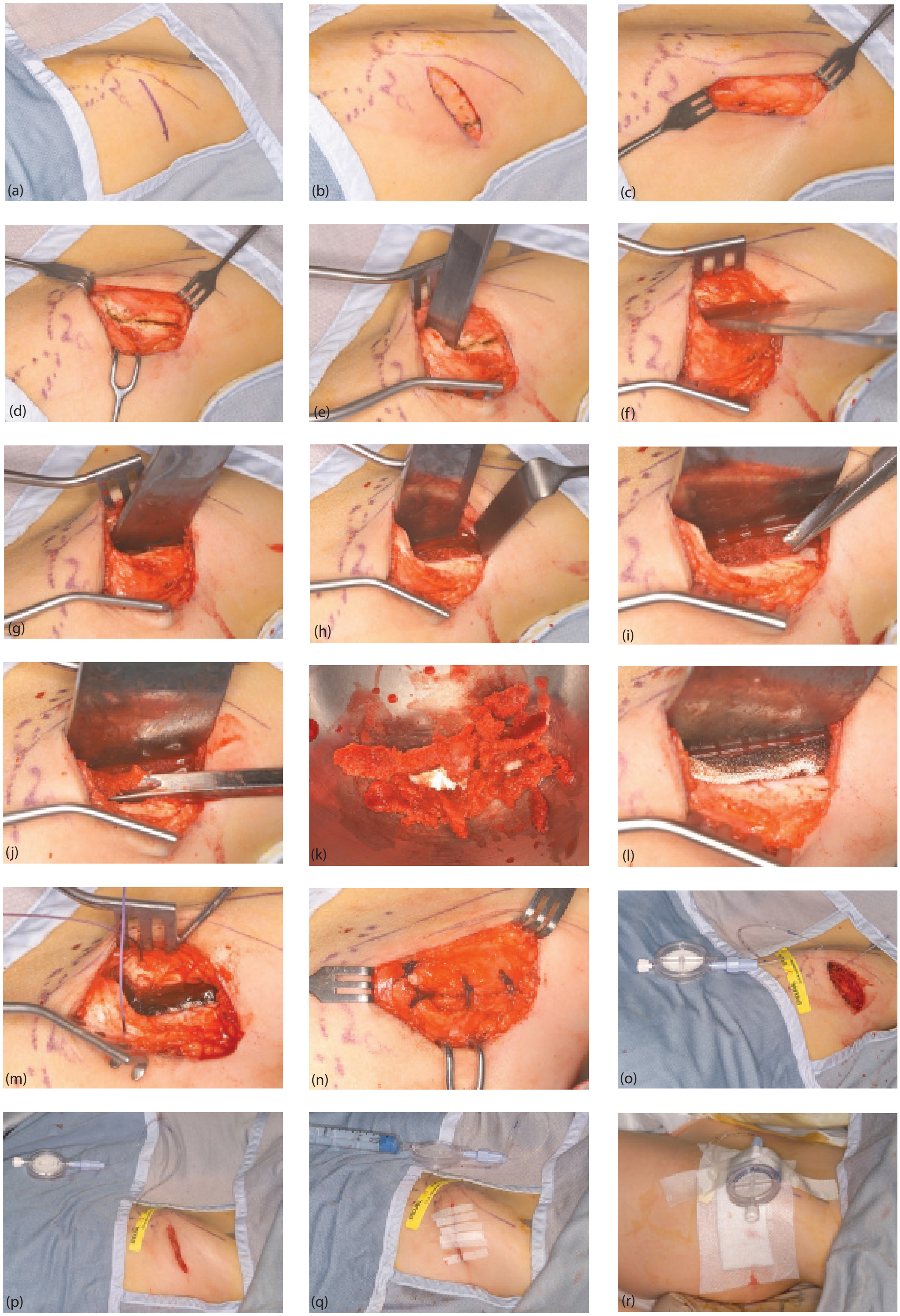


Figure 69.3 Harvest of autogenous cancellous bone from anterior iliac crest.

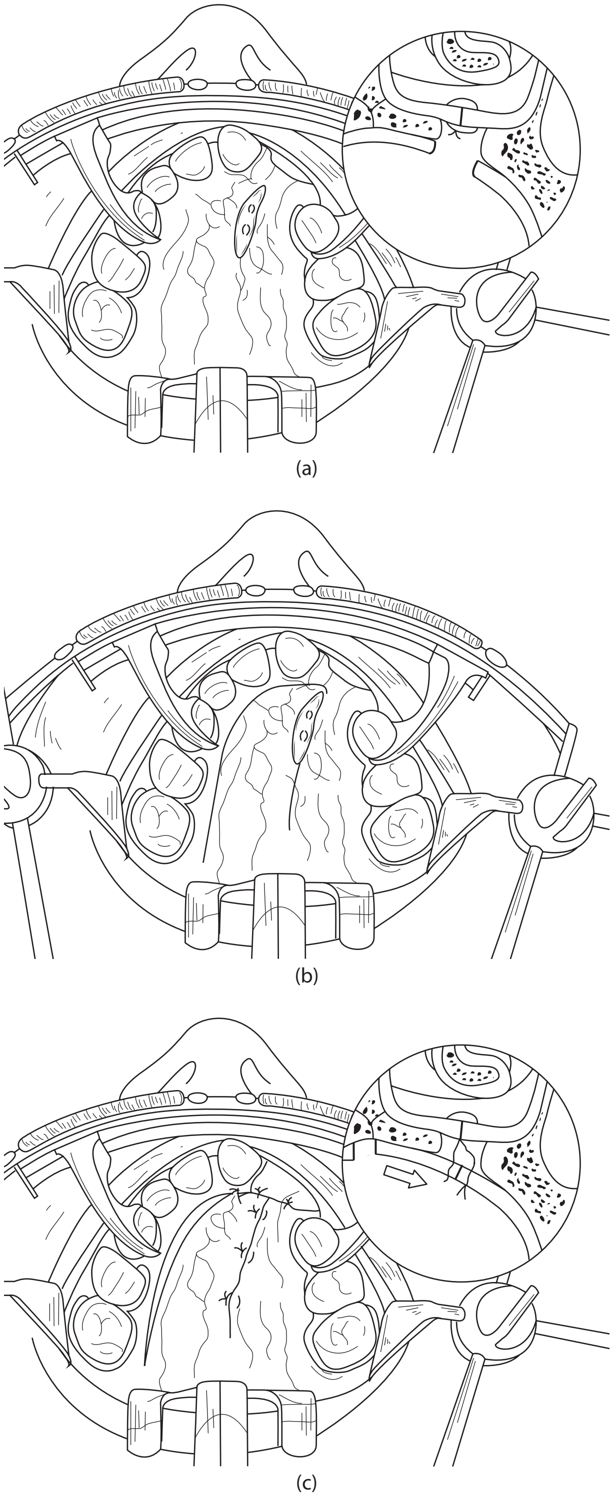


Figure 69.4 Small palatal fistula repair with one palatal flap in unilateral cleft.

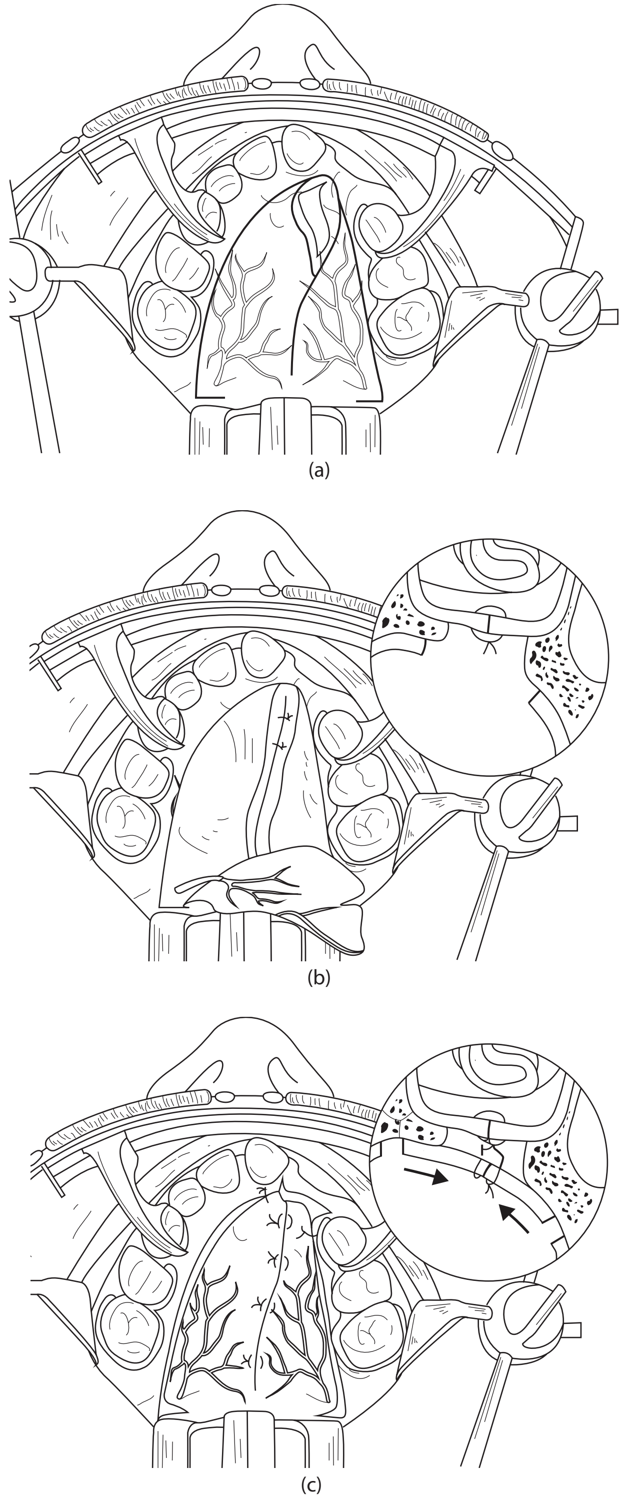


Figure 69.5 Large palatal fistula repair with two palatal flaps in unilateral cleft.

repair and the turbinate can be trimmed with diathermy. Sometimes, the lower end of the nasal septum may also obstruct the repair and this can also be trimmed. Together with excision of the scar tissue within the cleft, this nasal floor repair redefines the complete alveolar deficit into which is then packed the cancellous bone chips.

In unilateral cases, the mucoperiosteum on the greater segment is then sutured back into place with resorbable sutures (in bilateral cases, the central mucoperiosteum on the premaxilla should not have been raised) and the lateral flap on the lesser segment is then advanced, aided by appropriate horizontal sharp division of periosteum,

and closed with keratinized gingivae over the alveolar crest to the palatal oral mucosa and medially to the greater segment, all without tension. The posterior deficits of mucoperiosteum over the alveolus buccally from where the flap has been advanced is allowed to heal by secondary epithelialization.

In bilateral cases (Figure 69.8), the lateral segment muco-periosteal flaps are similarly advanced after periosteal release and sutured over the bone graft to the premaxillary mucosa and palate.

Antibiotics are administered intravenously during the operation.

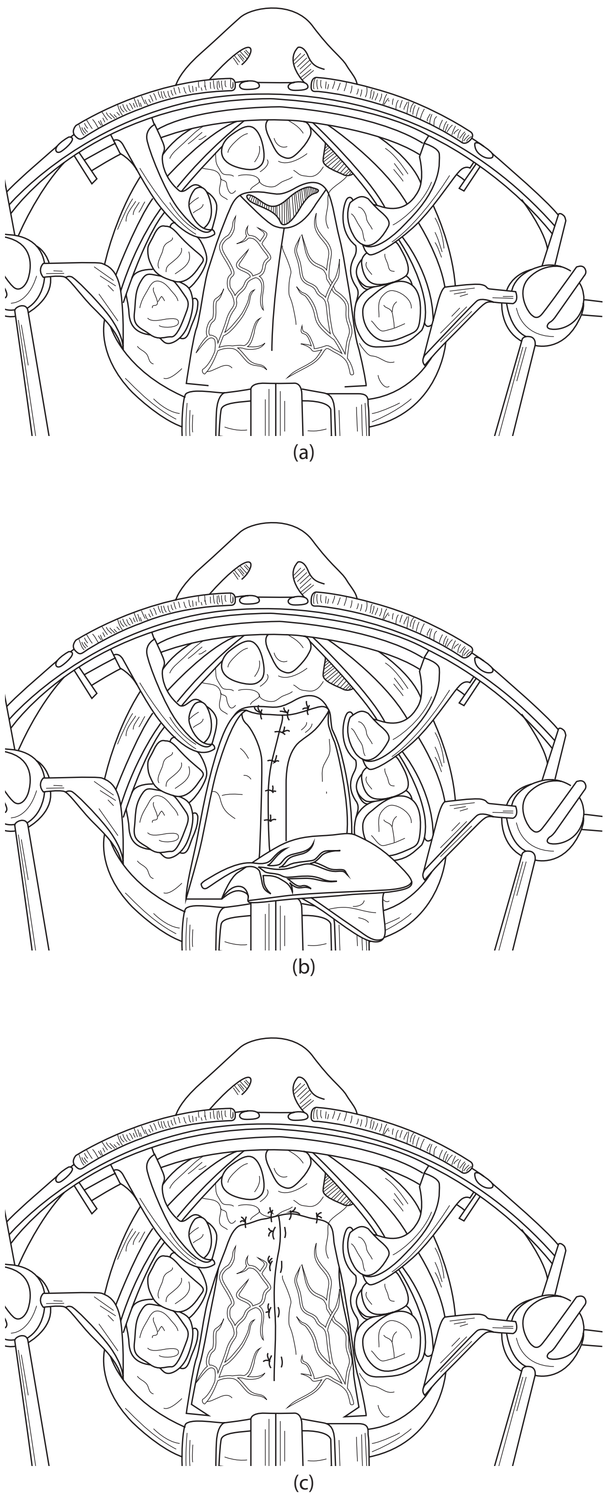


Figure 69.6 Large palatal fistula repair with two palatal flaps and advancement in bilateral cleft.

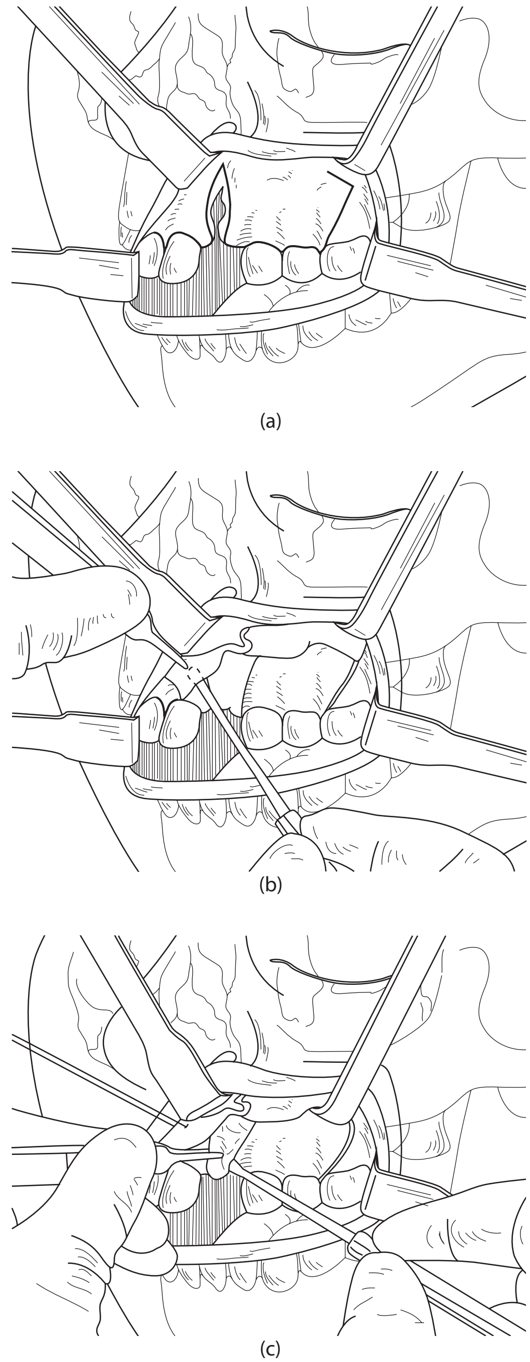


Figure 69.7 Unilateral alveolar bone grafting procedure. (a) Incisions marked. (b) Flaps raised. (c) Scar tissue excised from alveolar cleft. (d) Nasal floor repaired. (e) Bone graft being inserted into the alveolar defect. (f) Alveolar defect filled and lateral flap periosteum being divided. (g) Medial flap sutured, lateral flap advanced and sutured. (*Continued*)

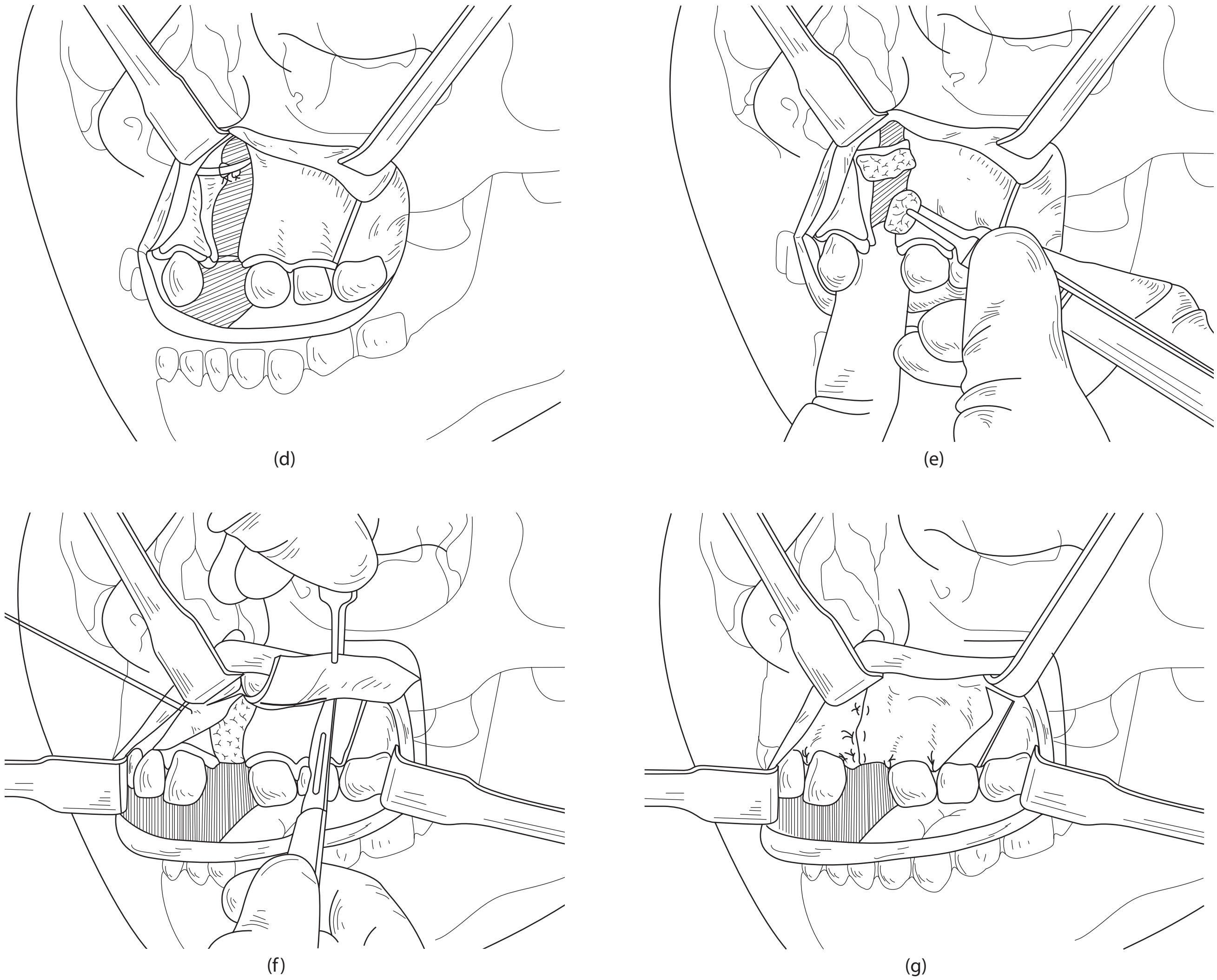


Figure 69.7 (*Continued*) Unilateral alveolar bone grafting procedure. (a) Incisions marked. (b) Flaps raised. (c) Scar tissue excised from alveolar cleft. (d) Nasal floor repaired. (e) Bone graft being inserted into the alveolar defect. (f) Alveolar defect filled and lateral flap periosteum being divided. (g) Medial flap sutured, lateral flap advanced and sutured.

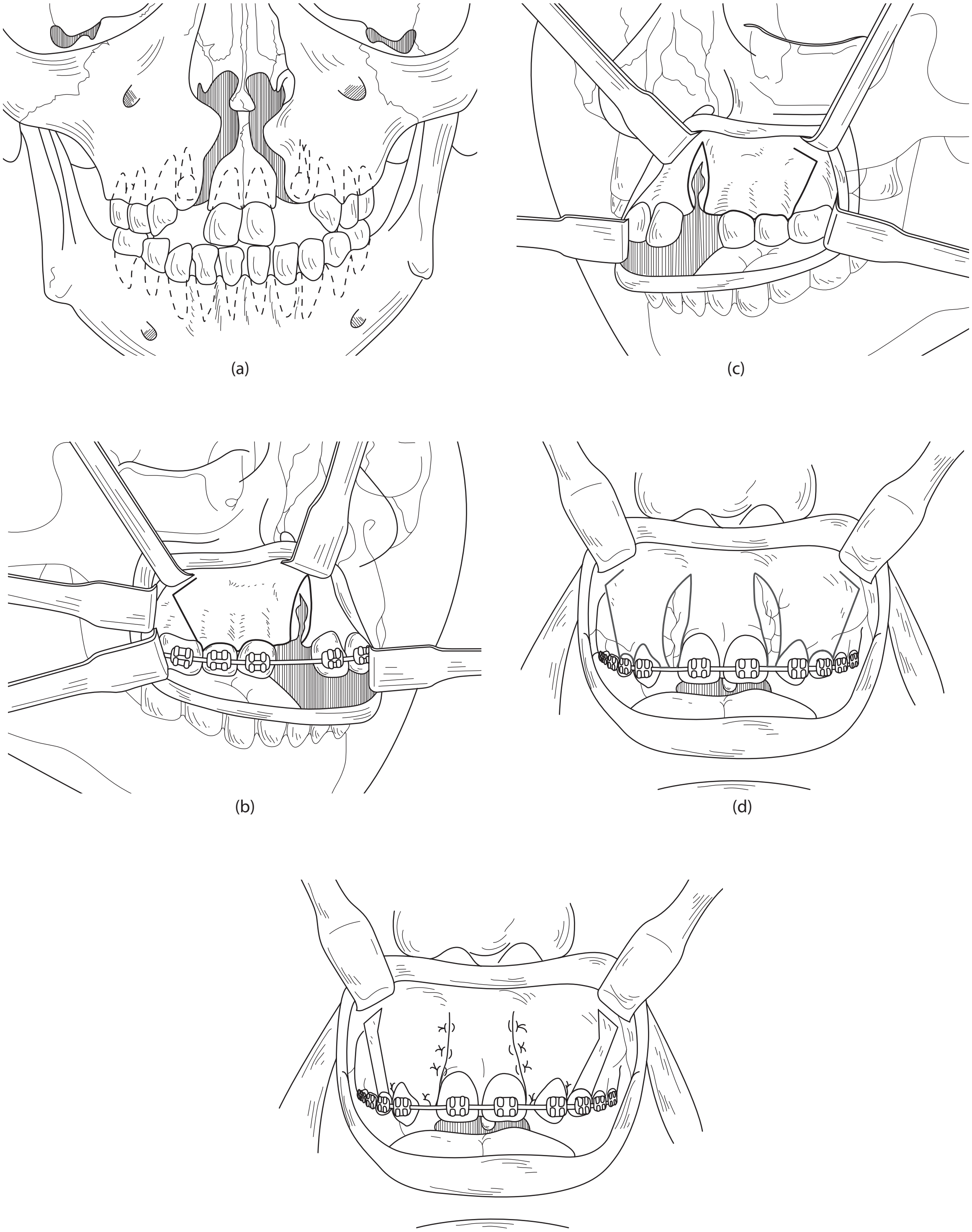
PREMAXILLARY OSTEOTOMY

In the preparation of patients with bilateral cleft lip and palate (especially bilateral complete cleft lip and palate) for ABG, it is common for the lateral segments and the premaxilla to need to be aligned and sometimes expanded orthodontically. Occasionally, it is difficult for a good position of the premaxilla to be achieved. It is also necessary for a freely mobile premaxilla to be stabilized for ABG surgery as a moving premaxilla may prevent bony union across the alveolar clefts.

In bilateral cleft lip and palate (BCLP), especially when complete, the bone of the premaxilla is attached very narrowly to the nasal septum. Its blood supply is derived principally from the labial mucoperiosteum. Occasionally that 'narrow' bony attachment to the nasal septum may be rather broader and more robust, and this may be why it sometimes proves resistant to orthodontic devices trying to move it. Also occasionally, the premaxilla is positioned inferiorly and is not amenable to being repositioned superiorly by non-surgical means. In those few cases in which the premaxilla is aberrant and cannot be repositioned orthodontically, a premaxillary osteotomy may be required. The anatomy as described above needs to be taken into consideration when designing the surgical approach and osteotomy technique if the premaxilla is not to lose its blood supply and become a free graft.

Only the differences between the bilateral and the unilateral procedures are shown in these diagrams. The premaxillary osteotomy is almost always carried out at approximately the same age as ABG and we will usually carry it out in conjunction with the bilateral ABG and, if required, palatal fistula repair all at the same surgical episode. It is possible to stage these procedures and we have done so rarely.

The bony attachment of the premaxilla may be approached from part of the incision used for the bone



(a) (c) (b) (d) (e)

Figure 69.8 Bilateral alveolar bone grafting procedure.

grafting procedure. This is demonstrated in Figure 69.9c and the only additional dissection required is a small area subperiosteally over the bony attachment to the septum. The osteotomy itself is carried out gently using a fine osteotome (Figure 69.9e). Sometimes bone has to be removed with Rongeurs or forceps. The premaxilla may then be moved digitally and placed in its new position with the guidance of an occlusal wafer. Fixation is best achieved with a preformed strong labial arch wire within pre-existing fixed orthodontic bands (Figure 69.9g).

Once the premaxilla is repositioned and stabilized, any palatal fistula is repaired and the bilateral alveolar bone

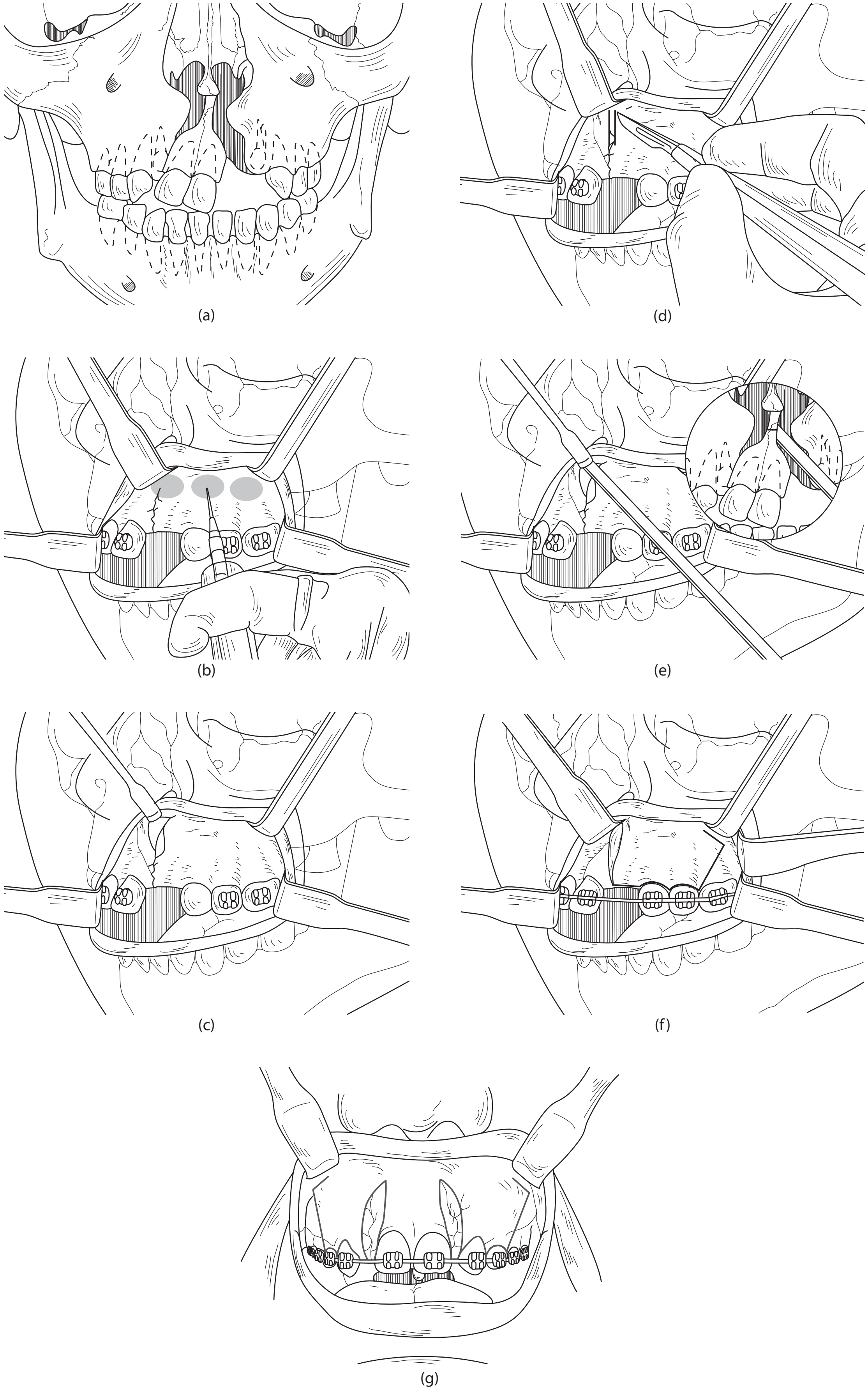


Figure 69.9 Premaxillary osteotomy and bilateral alveolar bone grafting.

Table 69.3 Typical sequence for a premaxillary osteotomy and bilateral alveolar bone grafting.

1) Model surgery to reposition the premaxilla and fabricate an occlusal wafer
2) Note any need for the removal of erupted or buried teeth and any part of the maxilla or premaxilla
3) Securing of orthodontic fixed bands and fabrication of a strong arch wire which will support the premaxilla in its new position
4) Surgery in which the premaxilla is approached through a small lateral incision permitting both the removal (if required) of some of the premaxilla and division with a small osteotome of its bony attachment some of which may also need to be removed to allow repositioning of the premaxilla
5) Digital movement of the premaxilla into its new position, temporary fixation into the preformed occlusal wafer and stabilization with a strong arch wire. The wafer is then removed.
6) Bilateral alveolar bone grafting with simultaneous repair of palatal fistula.
7) Continued orthodontics

grafting performed but this can be done at a later operation (Table 69.3).

Top tips

- Planning should be undertaken by the multidisciplinary team including the orthodontist and restorative dentist.
- The optimal age for alveolar bone grafting is just prior to the eruption of the canine tooth.
- Wide exposure of the bony cleft is essential.
- Tension-free closure of soft-tissue flaps is important for good healing.

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PERSPECTIVE II

TIM FLOOD

Introduction

There are many types of facial clefting disorders reported in the literature. The cleft lip and palate anomaly is the most common of these, being reported in approximately 1:700 live births. In 75 per cent of cleft lip and palate cases, the cleft runs through the alveolus.

Perhaps the most important development in the treatment of cleft lip and palate patients followed the work of Boyne and Sands and was the introduction of reconstruction of the alveolar cleft with bone, at a time when the growth of the maxilla is largely completed (secondary alveolar bone grafting). Attempts at alveolar bone grafting go back as far as 1901 when Von Eiselberg used a pedicled bone graft to fill the defect. However, in 1908, Lexter was the first to demonstrate the use of free bone grafts.

Classification

Alveolar bone grafting can be classified as follows:

- primary (0–3 years), often undertaken at the time of lip repair and now of historical significance only;
- early secondary (3–6 years), before the eruption of the permanent incisor teeth;
- secondary (6–13 years), before the eruption of the permanent canine teeth;
- late (after 13 years), after the eruption of the permanent canine teeth.

Presentation and treatment aims

Functional and aesthetic problems are associated with cleft lip and palate. The severity of these will depend upon the type of cleft (unilateral or bilateral).

Common presenting problems:

- discharge and smell from the nose;
- oral food/fluids leaking from the nose;
- poor speech;
- inability to suck up a straw or blow up balloons;
- poor appearance of the incisor teeth, which traumatize the upper lip;
- missing or supernumerary teeth within the cleft area, which are often decayed;
- difficulty cleaning teeth in the cleft area;
- poor facial appearance.

The objectives of alveolar bone grafting are therefore aimed at addressing the above complaints as follows:

- complete closure of all oronasal fistulas with significant improvement in speech;
- restoration of the continuity of alveolar/dental arch with bone;
- providing stability to the premaxilla and dental arch;
- allowing normal eruption of the permanent teeth in the cleft area and providing sufficient bone for the placement of dental implants, where needed;
- allowing orthodontic alignment of the maxillary dentition.

Additional benefits can also be achieved with reconstruction of the nasal floor and piriform aperture, as follows:

- improvement of nasal symmetry;
- a functional nasal airway;
- support for the upper lip.

Timing of surgery

Primary bone grafting was adopted by many centres in the 1950s and early 1960s; however, reports emerged demonstrating a significant detrimental effect of this procedure on maxillary growth. Secondary bone grafting was advocated by Boyne and Sands. This approach was popularized by further work undertaken by Abyholm et al. Where possible, alveolar bone grafting should be undertaken between the ages of six and 13 years. Perhaps the ideal age is eight years following the peak in maxillary growth and before the unerupted canine tooth has started to erupt from bone into the cleft. This is usually before the canine root has developed two-thirds of its final length. Waiting until maximal transverse growth of the maxilla has been achieved may avoid the need for presurgical maxillary expansion or at least minimize the presurgical orthodontic treatment required. Timing of surgery is largely guided by dental age, although other factors such as psychological development, speech and social circumstances should be taken into account in a multidisciplinary and child-friendly setting. Where the permanent canine tooth has already erupted into the cleft area, this will significantly compromise the graft and consideration should be given to delaying the grafting procedure until the canine is fully erupted and can be aligned by presurgical orthodontic therapy to optimize the surgical outcome.

Late alveolar bone grafting is known to be less successful. This is due to a number of factors including poor hygiene and tobacco smoking. This patient group, however, should not be excluded from treatment and it is important that alveolar bone grafting is offered to older patients requesting facial reconstruction and dental rehabilitation. Careful and comprehensive treatment planning is essential and most patients will require presurgical orthodontic treatment. It is essential that alveolar bone grafting precedes facial osteotomy surgery and reconstructive rhinoplasty for optimal results.

Patient assessment

Patients should be assessed within a multidisciplinary setting. A full history should focus on previous surgical episodes and complications related to these. Examination of the cleft area should note the presence of supplemental and supernumerary teeth and the presence of dental caries in the remaining dentition. Deciduous teeth which have erupted into the cleft will compromise the available soft tissue for flap reconstruction and should be removed prior to definitive surgery.

Photographic and radiographic records (panoramic, occlusal and periapical films) are essential for treatment and audit. Fully coned three-dimensional computed tomography (CT) scanning is becoming increasingly important as this gives full visualization of the cleft defect at a reasonable radiation dosage. When used post-operatively, it is possible to accurately assess the volume of successfully grafted bone and is a powerful audit tool.

Study models are obtained and, for the bilateral cleft cases, an interocclusal acrylic wafer is constructed to the predeter-mined agreed post-operative position of the premaxilla.

Surgical technique

Surgery is undertaken under general anaesthesia with nasal intubation in both unilateral and bilateral cases. Use of ilium is the author's preferred option for harvesting bone as this site reliably produces large volumes of donor bone and allows a second team to harvest bone simultaneously. Infiltration of the oral cavity with local anaesthetic solution with vasoconstrictor helps intraoperative haemostasis and dissection, and aids post-operative pain control. The mouth is irrigated with a chlorhexidine solution and prophylactic antibiotic therapy instituted and continued for 5 days. The primary objectives of the surgery are to close all oronasal fistulas and therefore the whole of the cleft area, including the hard palate, needs to be widely exposed. Scar tissue lying within the cleft alveolus and nasal floor area should be excised to create room for grafted bone.

BONE GRAFTING

Through a small incision over the iliac crest, dissection is taken to the perichondrium of the crest. The cartilaginous cap is divided along its length with stop cuts at either ends and the cartilage cap retracted medially to expose the inner aspect of the ilium. A corticocancellous block is now harvested with additional cancellous bone (Figure 69.10) The cortical sheet is now separated from the cancellous block and the cancellous portion morcellated. The wound is closed primarily with insertion of an epidural catheter into the wound to provide post-operative analgesia with a local anaesthetic solution.

UNILATERAL CLEFTS

Incisions for flaps are made starting in the buccal suclus posteriorly along the gingival margins from the upper first molar tooth to the cleft margin on the lesser segment (Figures 69.11 and 69.12)

A second flap is raised on the greater segment sufficient to expose the piriform aperture on the noncleft side.

Dissection is taken into the cleft incising along the cleft margins vertically and joining the incisions submucosally as they meet in the buccal sulcus above the cleft. Separate horizontal incisions are now made within the cleft on either side approximately 5 mm below the level of the palatal shelves and extending to the posterior extent of the cleft (Figure 69.13).

Bilateral Veau palatal flaps are raised as far posteriorly as possible to fully expose the cleft in the hard palate. Where necessary, a backcut is made medial to the molar teeth should advancement be required. The cleft is now fully exposed.

The medial margins of the Veau flaps are trimmed and approximated with a continuous suture (Figure 69.14).

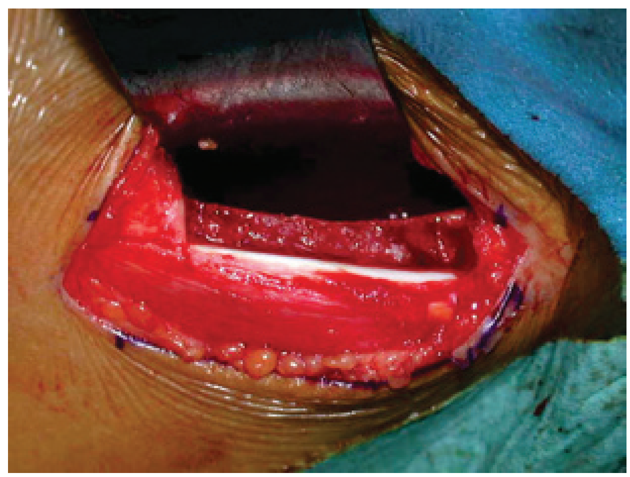

Figure 69.10 Cartilage splitting approach to ilium and volume of available bone.

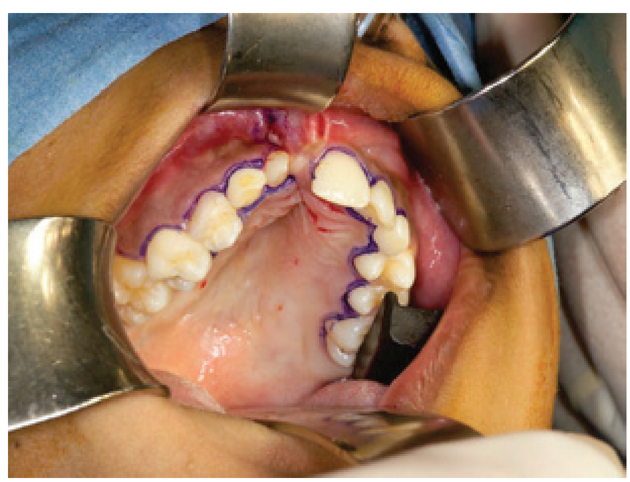

Figure 69.11 Planned incisions.

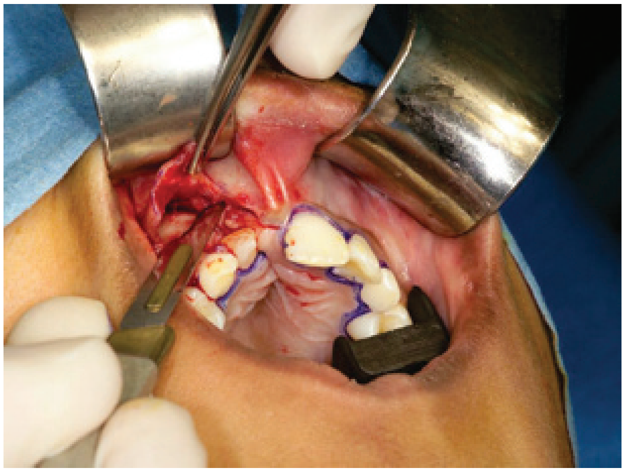

Figure 69.12 Dissection of labial mucoperiosteal flaps from the cleft area.

Figure 69.13 The horizontal incision into the cleft to separate the nasal layer from the palatal tissues with Veau flaps being elevated.

Where the inferior turbinate has hypertrophied and is lying within the cleft alveolus, this is trimmed to above the level of the palatal shelves as described by Iino (Figures 69.15 and 69.16)

Following removal of any excess mucosa, the nasal layer is approximated closing the fistula along its length. A thin sheet of cortical bone is inserted at the level of the piriform aperture reconstructing the nasal floor (Figure 69.17). A biomembrane (Bio-Gide®; Geistlich Pharma, Wolhusen, Switzerland) is placed above the cortical sheet which acts as a barrier to ingress of infection and promotes guided tissue regeneration.

Bio-Gide is also placed on the cleft surface of the approximated Veau flaps (Figure 69.18) and the cancellous bone chips are packed tightly into the cleft defect.

The buccal surface of the grafted cleft is then also covered with Bio-Gide and the buccal flaps transposed to cover the graft and sutured without tension (Figure 69.19).

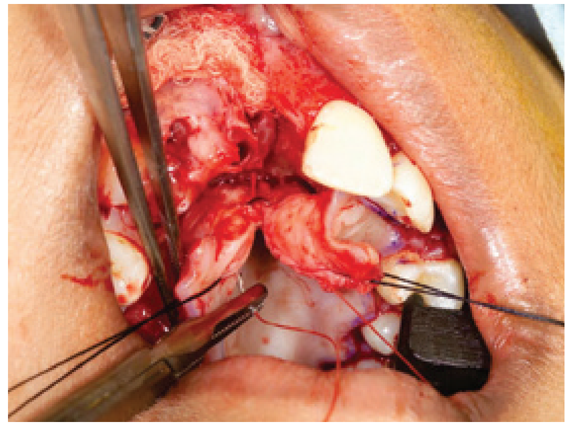

Figure 69.14 Approximation of the Veau flaps following wide exposure of the cleft area.

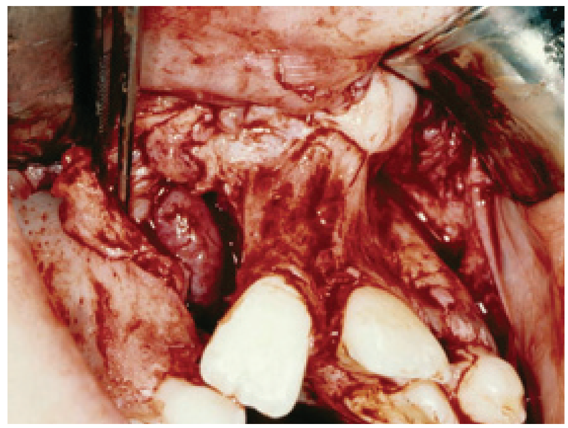

Figure 69.15 The hypertropy of the inferior turbinate lying within the alveolus area of the cleft.

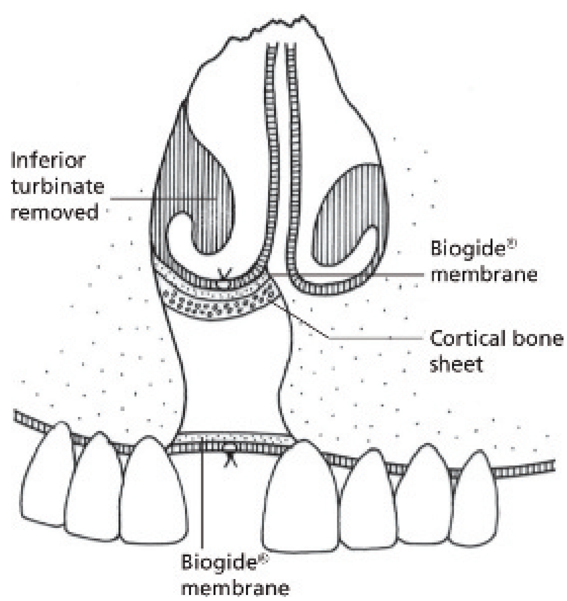

Figure 69.16 Inferior turbinectomy and reconstruction of the nasal floor with a Bio-Gide biomembrane overlying a thin sheet of cortical bone.

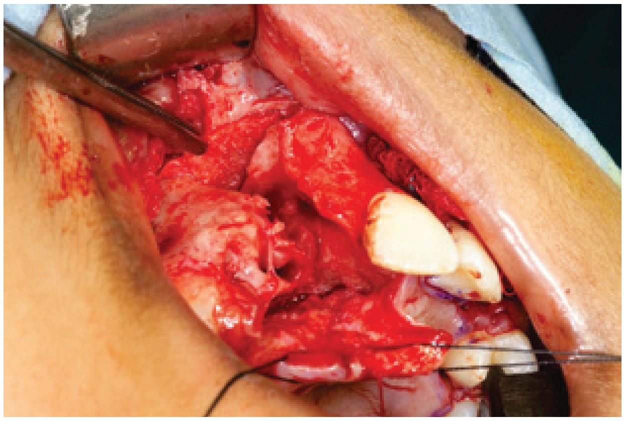

Figure 69.17 Formal reconstruction of the nasal floor at the level of the piriform aperture with a thin sheet of cortical bone.

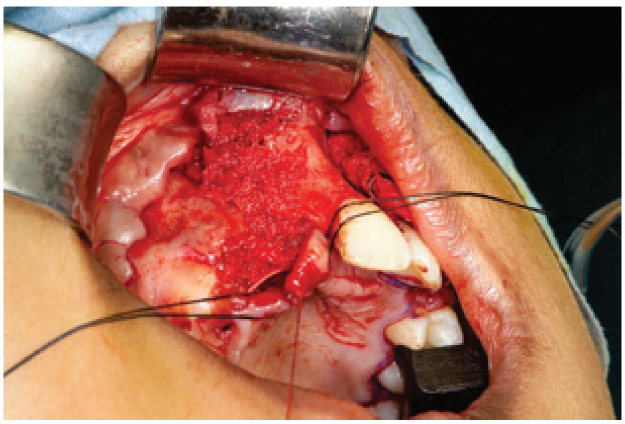

Figure 69.18 Reconstruction of the alveolus with cancellous bone chips. Note the Bio-Gide biomembrane on the palatal surface of the bone.

Rotation of these flaps ensures a satisfactory sulcus depth in the cleft area.

BILATERAL CLEFTS

Full exposure of the bilateral cleft is required for closure of the nasal layer and to facilitate a reliable palatal flap repair. The surgical technique therefore includes premaxillary osteotomy which allows repositioning of the premaxillary segment to an optimal position determined pre-operatively following consultation with the left orthodontist. An acrylic wafer is constructed on the study model to aid fixation of the premaxilla post-operatively and the orthodontist is asked to band and place brackets on the maxillary teeth.

Buccal mucoperiosteal flaps are raised as before; however, special care is taken when performing the vertical incision on the premaxillary side of the cleft (Figure 69.20). The mucoperiosteum on the labial aspect of the premaxilla has to remain attached on a wide base to

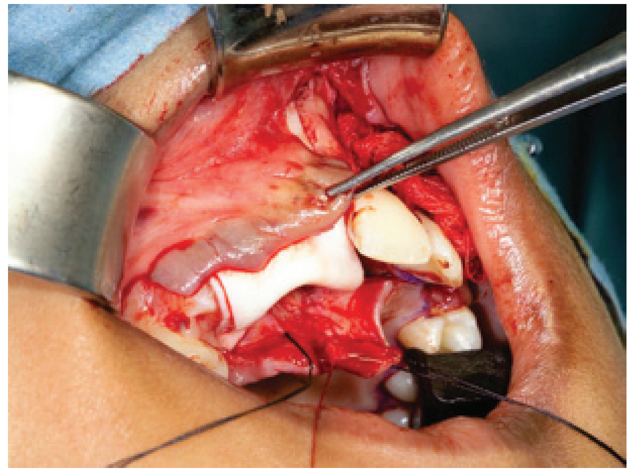

Figure 69.19 The graft covered with Bio-Gide and the mucoperiosteal release flap rotated to cover the graft without tension.

Figure 69.20 Incisions in a bilateral case.

the premaxilla as this will form the vascular supply to the premaxillary segment.

Horizontal incisions into the cleft on either side re made at the level of the nasal floor and these are extended to the midline and join on the palatal aspect of the premaxilla and are designed in such a way as to leave a generous cuff of mucosa attached to the premaxilla. The posterior horizontal incisions inside the cleft are then extended as one incision in the midline over the caudal end of the hypertrophied vomerine/maxillary suture freeing up the whole of the nasal mucosal layer (Figure 69.21).

The vomerine/maxillary suture area is now osteotomized with either a small osteotome or drill. The premaxilla can now be reflected in a superior direction based on the labial pedicle and the nasal layer is closed along the length of the cleft (Figure 69.22).

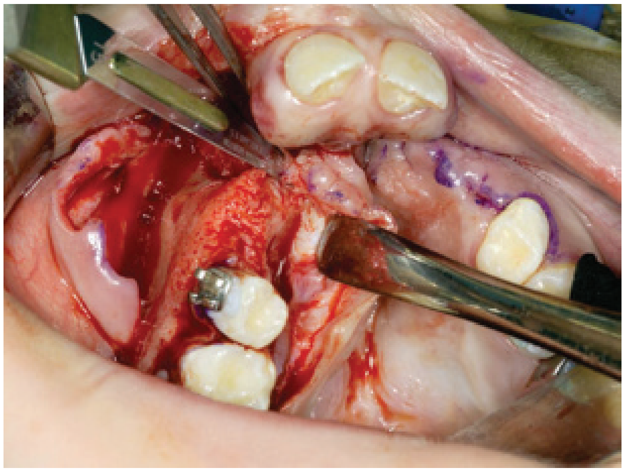

Figure 69.21 Division of nasal and palatal tissues and elevation of flaps. Note the generous cuff of mucosa on the palatal aspect of the premaxilla.

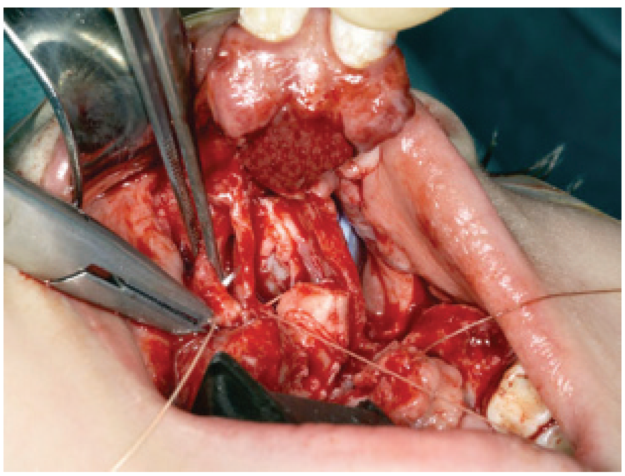

Figure 69.22 The osteotomized premaxilla is retracted anteriorly allowing excellent vision for accurate closure of the nasal layers.

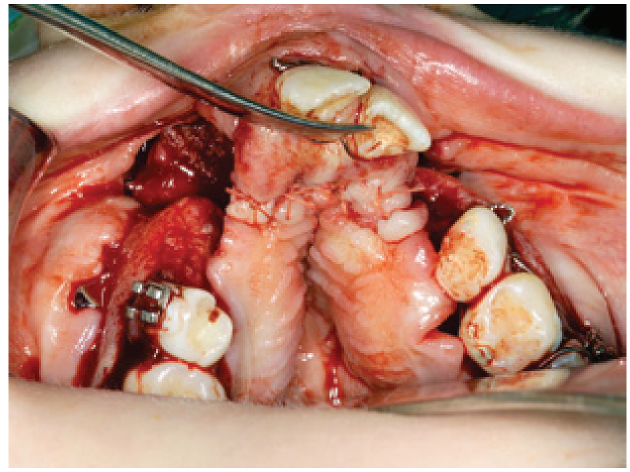

Figure 69.23 The premaxilla is repositioned and palatal tissues approximated prior to final placement of the cancellous graft.

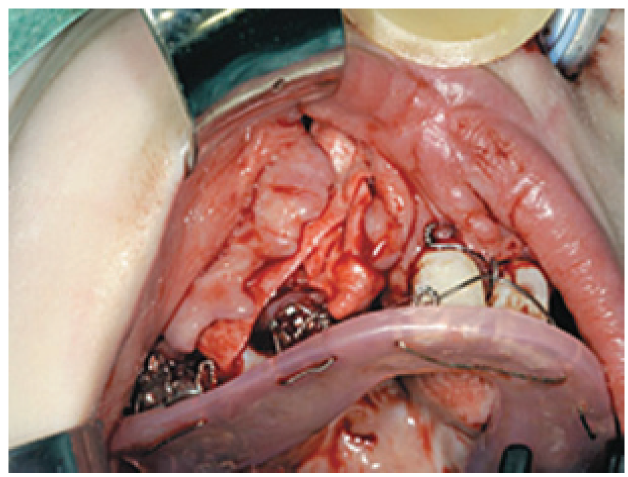

Figure 69.24 Rigid fixation of the premaxilla into a locating wafer prior to final closure over the Bio-Gide biomembrane covering the graft.

Finally, bilateral Veau flaps are raised, as described previously, with backcuts if necessary to give additional length. These are trimmed medially and approximated. A cortical bone sheet, covered by Bio-Gide, is now placed on both sides of the cleft and a further sheet placed to bridge the palatal shelves to reconstruct the nasal floor. The premaxilla is repositioned in the planned post-operative position and the attached lingual cuff of mucosa sutured to the Veau flaps across the width of the anterior palate (Figure 69.23).

Bio-Gide is placed on the inside of the suture line and cancellous bone is packed into the cleft defect from both sides and covered with further Bio-Gide. Finally, the buccal mucoperiosteal release flaps are rotated and advanced to cover the grafted clefts and sutured into place (Figure 69.24). The acrylic wafer is now wired into place securely.

Post-operative care

Antibiotics and a chlorhexidine mouthwash are continued for 1 week and the patient is placed on a liquidized diet and strict oral hygiene measures for 3 weeks. Ambulation is encouraged on the first post-operative day. Complications are rare with these procedures, although minor wound dehiscence is not uncommon. Infection of the graft is the most serious complication and where dehiscence occurs, it is wise to extend the prophyactic antibiotic cover.

Top tips

- Planning of treatment is best undertaken in a multidisciplinary team setting.
- Optimum age for alveolar bone grafting is between seven and nine years of age.
- Wide exposure of the cleft is essential for success.
- Ilium is a reliable source of cortical bone sheets and large volumes of cancellous bone.
- In the bilateral case, premaxillary osteotomy, combined with guided tissue regeneration, followed by a period of rigid fixation produces predictable results.
- Computed tomography is a powerful audit tool as bone volumes can be measured accurately.
- It is essential that alveolar bone grafting precedes facial osteotomy surgery and cleft rhinoplasty for optimal results.

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Cleft rhinoplasty

V ILANKOVAN and TIAN EE SEAH

CONTENTS

INTRODUCTION

Despite all the improvements in primary cleft surgery, cleft nasal deformity still remains a functional and aesthetic dilemma for patients and surgeons.

There is inherent composite tissue abnormality or hypoplasia. The developmental problems therefore can be divided into the following three categories: the covering, the framework (bone and cartilage) and the lining. The questions are: what are the deformities and what is the optimal time for correction?

There is adequate information in the literature that early limited correction of the lower lateral cartilage provides no subsequent growth disturbance, allows better nasal growth and reduces the psychological trauma to the child. Developmentally, the explanation falls into two distinct factors, which are responsible for the cleft nasal deformity. First, there is agenesis of tissue due to the lack of mesodermal and ectodermal quantity. Second, there is associated deformation as a result of mechanical stresses located within the cleft margins.

The deformities of the unilateral cleft nose are as follows:

- Septum
  - Perpendicular plate deviating to the cleft side
  - Quadrangular septal cartilage deviating caudally towards the non-cleft side
  - Nasal spine deviating to the non-cleft side
- Dorsum
  - Bony pyramid deviating to the non-cleft side
  - Asymmetry of the nasal bone and flattened at the cleft side
  - Asymmetry of the upper lateral cartilage on the cleft side
  - Disturbed junction between the upper and lower lateral cartilages on the cleft side
  - Downwards displacement of the lower lateral cartilage on the cleft side
  - Tendency to bifidity
  - Buckling of the lateral crura on the cleft side
  - Reduced height of the medial crura on the cleft side
- Columella
  - Deviation at the top to the cleft side and at the base to the non-cleft side
- Alar base
  - Lateral displacement resulting in a horizontal rotation of the nostril at the cleft side

The deformities of the bilateral cleft nose are as follows:

- Septum
  - No specific deviation
  - Disturbed caudoventral outgrowth
- Dorsum
  - Lack of projection and flattening of the osseo-cartilaginous vault
  - Disturbed junction between the upper and lower lateral cartilages
- Tip
  - Bifidity
  - Downwards of the lateral crura on both sides
- Columella
  - Very short
- Alar base
  - Lateral displacement resulting in horizontal rotation of both nostrils

Alveolar cleft, hypoplasia and retroposition of the maxilla compound the nasal deformity.

We divide our approach to the cleft rhinoplasty into four stages. They are as follows:

1. Rhinoplasty procedures at the time of primary cleft lip surgery
2. Cleft rhinoplasty during the pre-school years
3. Cleft rhinoplasty once growth has stopped
4. Definitive rhinoplasty

Pre-operative assessment is the most important step. The family's and patient's impression of the deformity and their expectations should be discussed in detail. The aim is always improvement and not perfection. There is an overlap between the third and fourth steps repairing and the patients need towards other corrective procedures.

RHINOPLASTY PROCEDURES AT THE TIME OF THE PRIMARY CLEFT LIP SURGERY

We describe two different approaches. One is based on McComb's technique where patients undergo pre-surgical orthopaedics and the other is based on Ahuja's technique, where no pre-surgical orthopaedics is carried out.

Unilateral

At the time of the lip repair, the skin of the nose on the cleft side is freed from the underlying bony and cartilaginous skeleton. Sharp pointed scissors are passed up through the incision in the upper buccal sulcus on the side of the cleft, extending the dissection over the cleft half of the nose. The same scissor is also used to free the dome of the alar cartilage and medial crura. The dissection is carried out in this same plane up to the nasion.

Now the affected lower cartilage can be easily lifted upwards with the attached nasal lining.

The alar lift is maintained by two mattress sutures (Figure 70.1). A straight needle with 3-0 nylon suture is started at the nasion, just cranial to the dissection boundary. The needle is passed through the intracrural angle into the nostril. A bolster is passed through the needle, and then the needle is passed through the nasal lining and lateral crura and then passed subcutaneously to the exit point at the nasion. Here, another bolster is applied and the two ends of the suture are held in a clip and the needle is cut off. A similar second suture is placed, if necessary, towards the lower third of the lateral crura (Figure 70.2). Alar lift is carried out to the desired contour, compared to the non-cleft side and both sutures held in a clip until the primary lip repair is completed. The final knotting is completed once a desirable height is contoured. The mattress sutures are removed at 5–7 post-operative days.

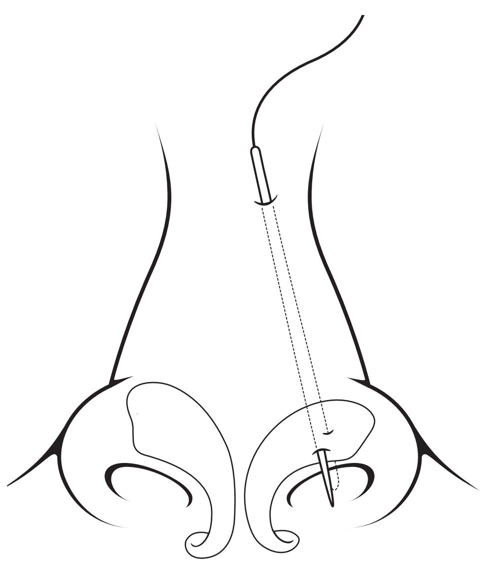


Figure 70.1 First mattress suture in a unilateral cleft placed via the intercrural angle.

Bilateral

The procedures are carried out exactly the same as in the unilateral procedures; however, there is no landmark to position the alar lift. The upper lateral cartilages should normally be at the same height as the lower lateral cartilage. Therefore, the aim of lifting should be to the height of the upper lateral cartilage and to reduce the nostril size equally (Figures 70.3 and 70.4).

This is based on Ahuja's 'limited open' approach, where elevation, medial rotation and suture fixation of the lateral crura, reconstruction of the nostril sill, alar base positioning and correction of the vestibular webbing is carried out along with lip repair.

The nasal tip and lower half of the dorsum are exposed and an inverted U incision on the cleft side and a marginal incision on the non-cleft side are made (Figure 70.5).

The inverted U incision on the cleft side is joined with the buccal sulcus incision. The upper half of the medial crura, the dome and the lateral crura of both alar cartilages are dissected from the dorsal nasal skin. The base of the lateral crura on the cleft side is released from the pyriform margin.

A single horizontal mattress suture of undyed 5-0 Prolene on a round-bodied needle approximates the two domes to elevate the lower lateral crura on the cleft side (Figure 70.6).

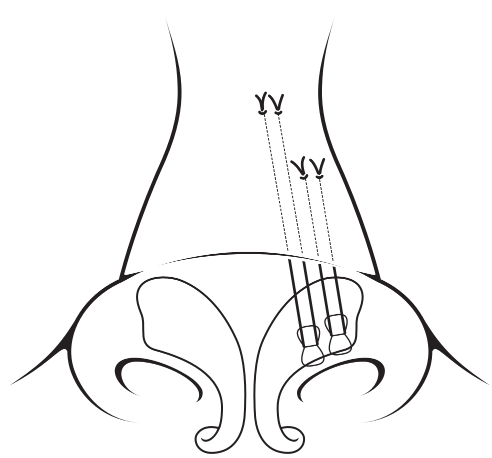


Figure 70.2 Second mattress suture placed towards the lower third of the lateral crura.

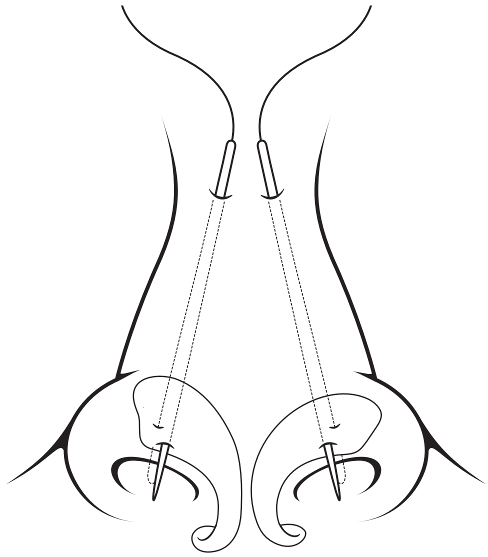


Figure 70.3 First mattress suture in bilateral cleft.

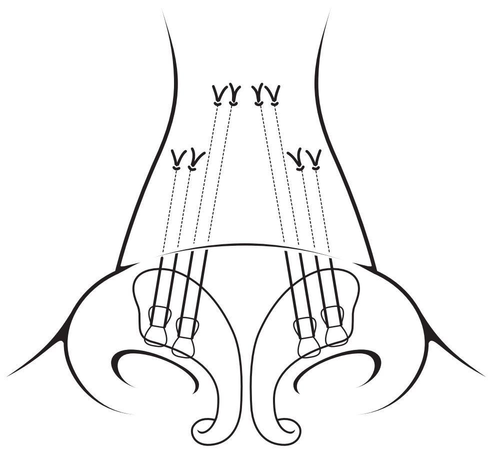


Figure 70.4 Second mattress suture in bilateral cleft.

Figure 70.5 Inverted U incision on the cleft side and the marginal incision of the non-cleft side.

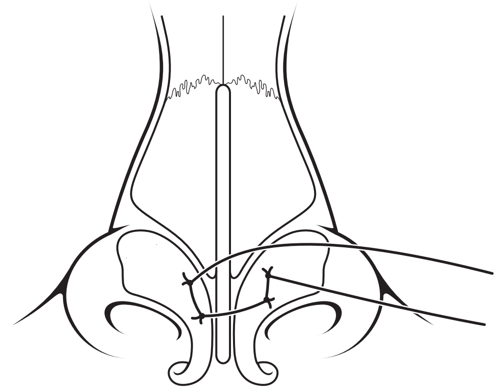


Figure 70.6 Horizontal mattress suture from the cleft side to the non-cleft side.

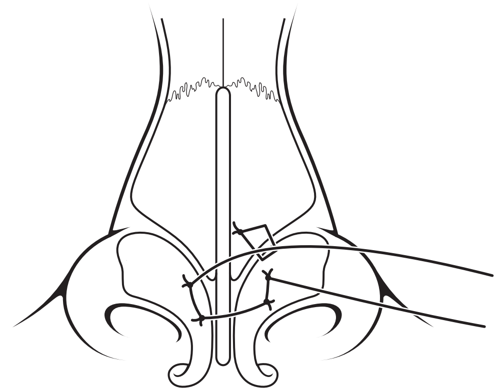


Figure 70.7 Second horizontal mattress from the lateral crura on the cleft side to the lower end of ipsilateral upper lateral cartilage.

A second suture of the same material is used to fix the lateral crura on the cleft side to the lower end of the ipsilateral upper lateral cartilage (Figure 70.7). This mattress suture is placed in a differential manner at both ends depending upon the adjustment required. On the cleft side from the lip repair, the part of the advanced mucosa is fed into the vestibular incision to compensate for the shortage of the lining that can lead to the vestibular web or fold.

The cleft lip is repaired in the usual way, together with reconstruction of the nostril sill and floor.

A suitable nasal splint is placed and maintained as long as possible (Figure 70.8). Ahuja recommends a vaseline gauze for 5–7 days. The authors prefer a nasal splint.

Bilateral inverted U incisions are used. Dissections of the upper half of the medial crura on both side as well as the dome and lateral crura from the overlying skin are performed. The bases of the lateral crura on both sides are dissected from the pyriform margins.

The desired alar height in relation to the height of the upper lateral cartilage is established and the sutures placed accordingly. The advanced mucosa from both sides of the lip repair is fed into the vestibular incisions (Figure 70.9).

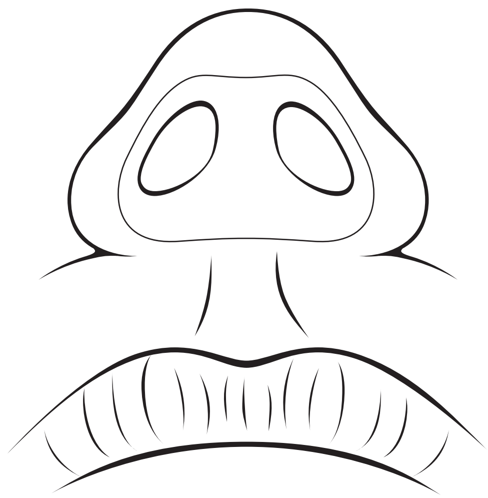


Figure 70.8 A silicone nasal implant in situ.

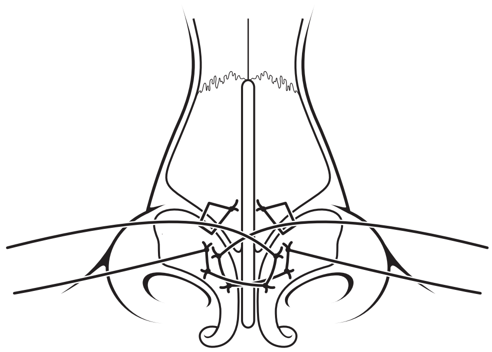


Figure 70.9 Two horizontal mattress sutures placed for bilateral clefts.

The bilateral cleft is repaired in the usual way together with reconstruction of the nasal sill and floor. Suitable nostril splints are placed and maintained as long as possible.

CLEFT RHINOPLASTY DURING THE PRE-SCHOOL YEARS

Unilateral

A mid-columella transverse incision is made across the columella. It is extended superiorly on the inner edge of the columella to the dome, continuing as an infracartilaginous incision down to the pyriform aperture. The lower lateral cartilage and upper lateral cartilages are exposed (Figure 70.10). The fibrous attachment of the lower lateral cartilage to the upper lateral cartilage and the rim of the maxilla are freed by sharp dissection. The interdomal attachments between both lower lateral crura are also freed. This should allow the lower lateral cartilage to be completely free and mobile, allowing it to be evaluated for mucosal tethering on the lateral end.

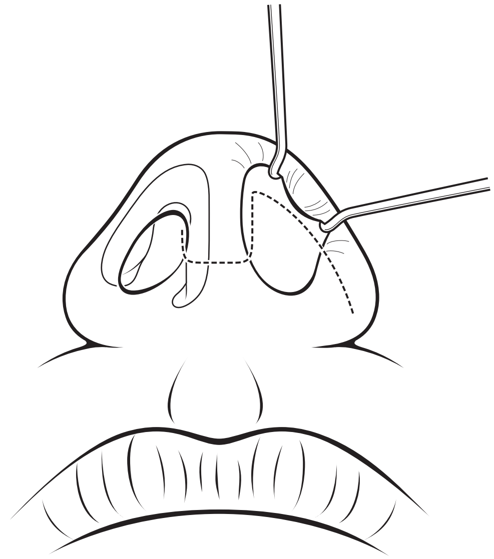


Figure 70.10 A mild columella transverse incision with bilateral infracartilaginous incision.

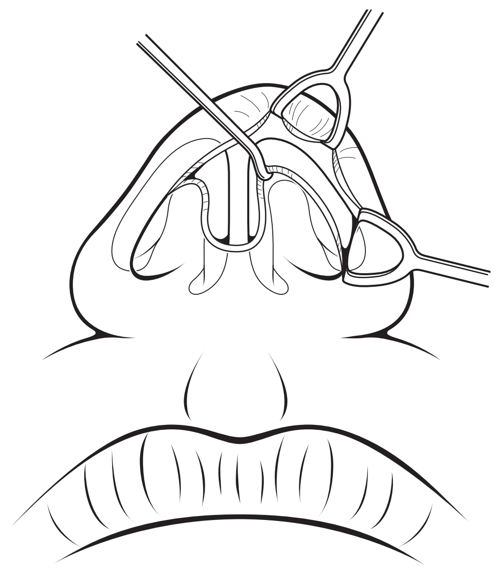
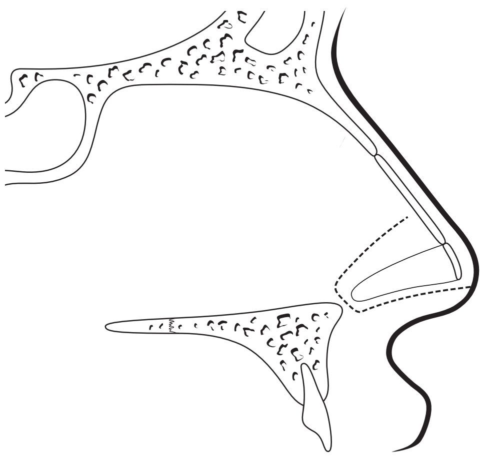


Figure 70.11 The required mobilization on the cleft side is assessed by placing a skin hook.

The deficiency of the cleft side mucosa is evaluated by placing a hook in the intermediate crural margin and advancing the freed lower lateral cartilage with attached mucosa to match the height of the non-cleft side (Figure 70.11). If there is tethering of the lower lateral cartilage, re-evaluation of the previous release of the lower lateral cartilage from the upper lateral cartilage and the rim of the maxilla is made to ensure that only the mucosal attachment remains (Figure 70.12a and b). If the mucosa is still tight and limits elevation of the lower lateral cartilage, an inferior turbinate mucosal flap is raised, which is attached to the lower lateral cartilage and the mucosa and this flap is completely elevated into the pyriform fossa.

(a)



(b)

Figure 70.12 (a) Frontal view of lateral mucosa dissection towards the inferior turbinate. (b) Lateral view showing the inferior turbinate mucosal flap.

Figure 70.13 Two mattress sutures placed at the apex of the middle crura and the lateral crura to the upper lateral cartilage.

After release of the lower lateral cartilage and correction of the mucosal deficiency, the chondromucosal unit is advanced into its correct position and held in two places. First, it is fixed to the apex of the medial crura, which is fixed to the opposite side medial crura on the non-cleft side (Figure 70.13). Second, the lateral third of the lower lateral crura on the cleft side is fixed to the lower part of the upper lateral crura. No sutures are placed into the septal cartilage.

The skin is redraped and closed over with 6-0 Prolene sutures. Additional support can be provided with alar transfixation sutures to the skin at the alar crease. The number can vary from one to three (Figure 70.14). The advantages are that it reconstitutes the alar crease, supports the nasal tip projection and prevents vestibular webbing.

A suitable nostril splint is applied and maintained as long as possible. The sutures are removed in the seventh post-operative day.

Bilateral

A mid-columellar transverse incision is made across the columella (Figure 70.15) similar to the unilateral approach; here a bilateral approach is made along the columella and along the infracartilaginous area. The whole of the lower half of the nose is exposed after blunt and sharp dissection. Bilateral inferior turbinate flaps are raised to ensure that there is no mucosal tethering (Figure 70.16). The chondromucosal unit is advanced to an acceptable height and held by two sutures as before.

The skin is redraped and closed with 6-0 Prolene sutures. Additional sutures can be provided with alar transfixion sutures bilaterally.

When redraping the columella skin, if there is a deficiency along the columella, a composite earlobe graft can be used in the defect. A word of caution here, if the bed vascularity is not adequate, the graft may not take.

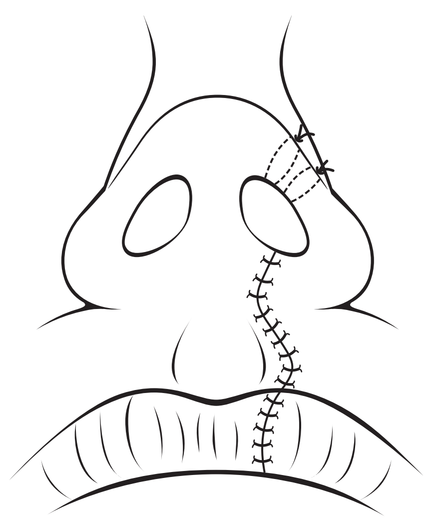


Figure 70.14 Alar transfixation to the skin at the alar crease.

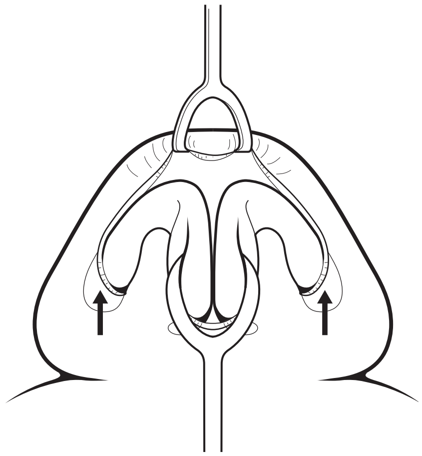


Figure 70.15 Mild columellar incision and bilateral infracartilaginous incision extending towards the inferior turbinate.

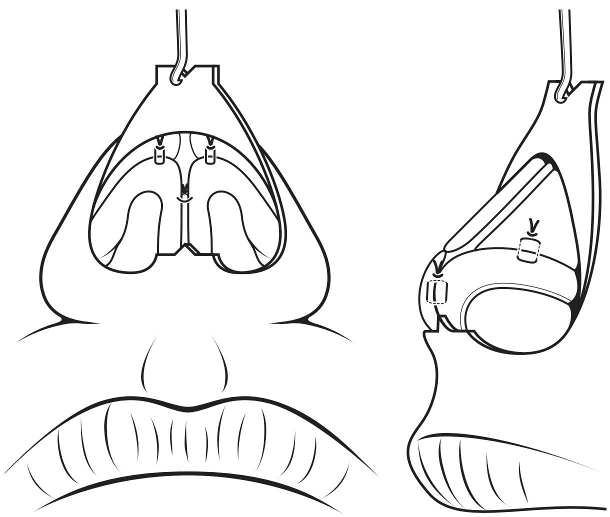


Figure 70.16 Bilateral inferior turbinate chondro-mucosal flaps and placement of three sutures as before.

CLEFT RHINOPLASTY ONCE GROWTH HAS STOPPED

Septal correction

The approach is twofold. First is a dorsal approach once the nasal lobule is degloved via columellar and infracatilagionous incisions. The second is hemi-transfixion incision in any septoplasty procedure.

In the former, the medial crura and fibrous attachments are separated and a mucoperichondrial flap is raised to the base of the nasal floor from above.

The anterior nasal spine is inspected and if it is displaced, a 3-mm osteotome is used to mobilize it from the maxillary bone to correct the midline. Once the midline position is stabilized, the soft tissues are attached with a 4-0 polydioxanone (PDS) round-bodied suture.

The lower one-third of the septal cartilage is resected and a septal straightening is carried out in the usual way (Figure 70.17).

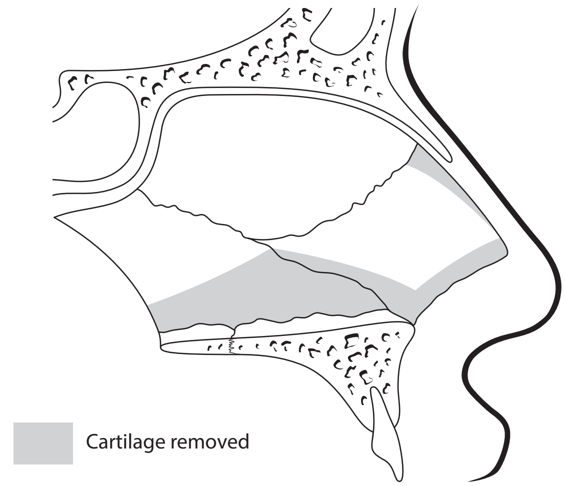


Figure 70.17 Areas marked where the septal cartilage is removed.

If the approach is carried out via a hemi-transfixion incision, a mucoperichondrial and mucoperiosteal dissection is carried out in order to expose both sides of the cartilaginous and bony part of the nasal septum. Then the lower third of the nasal cartilage together with the vomerine bone, if required, is removed. This would aid in centralizing the nasal septum.

The cartilage, which has been removed, is used as graft material.

Lower lateral cartilage correction

The lower lateral cartilage from the cleft side is dissected from the nasal skin and the lining. Sharp curved dissecting scissors are very valuable in this procedure.

The required amount on cephalic excision is carried out to create an alar crease (Figure 70.18). This is carried out bilaterally. Due to the cleft-side hypoplasia, the amount of cephalic excision would be less than the noncleft side.

The removed septal cartilage, or separately harvested conchal cartilage, is used to support the lower lateral cartilage in a tailor-made fashion (Figure 70.19). The septal cartilage can be trimmed to form an intercrural graft. Conchal cartilage can be used as an onlay graft to the lateral crura or as an extension from an intercrural graft to the lower lateral cartilage contour.

The intercrural graft sits on the anterior nasal spine and is stabilized to the desired height with two or three 4-0 PDS round-bodied mattress sutures, holding the medial crura (Figure 70.20). In the past, the non-cleft side lower left cartilage was dissected in its entirety and it was found that it was not necessary to do so unless there is gross secondary deformity. In spite of mobilization and stabilization, the dome height may not be equal. Next, an onlay graft should be placed over the intermediate crura and sutured with 4-0 PDS sutures. It is preferable to place the knot on the dorsal surface.

Figure 70.18 Selective cephalic excision.

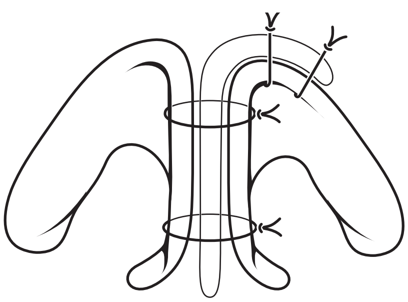


Figure 70.19 Intercrural graft with extension into the dome of the cleft side and stabilized with mattress sutures.

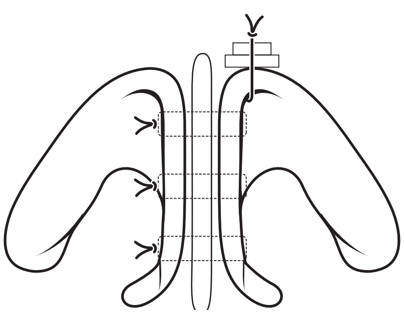


Figure 70.20 Intercrural graft stabilized with mattress sutures and only graft along the dome of the cleft site.

If there is gross hypoplasia of the lower lateral cartilage, a conchal cartilage can be used as an intercrural graft and onlay graft to provide support and height.

Once the symmetry of the nasal lobule is achieved, a horizontal mattress suture is placed from the lower end of the upper lateral cartilage to the upper end of the lower lateral cartilage, along the lateral third of the affected side (Figure 70.21).

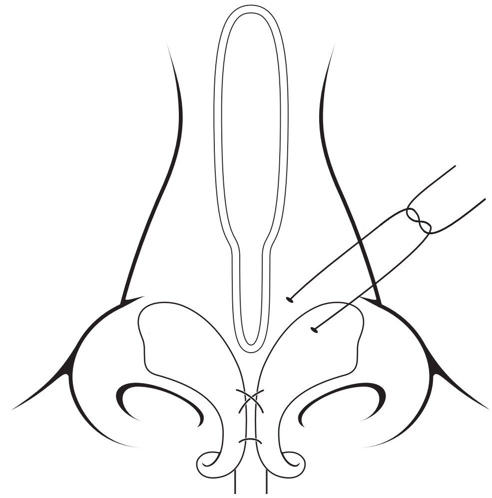


Figure 70.21 Horizontal mattress suture from the lateral crura to the ipsilateral upper lateral cartilage.

Correction of lining deformity

If there is lining deficiency in spite of good mobilization of the fibrous attachment to the maxilla, a finger extension to the inferior surface of the inferior turbinate is obtained.

The benefit of mobilizing the nasal lining on its own is the freedom to overcome any webbing deformity and in turn provide a symmetrical nostril shape. The disadvantage, however, is introducing further scarring on the ventral surface of the lower lateral cartilage.

Hump reduction and medial and lateral osteotomy

A dorsal hump reduction is carried out by resecting the cartilaginous hump with a blade. Following that, the bony hump is osteotomized with a Rubin osteotome and removed. When hump reduction is performed, medial osteotomies are not necessary for nasal infracture. If a hump reduction is not needed, a *midline osteotomy of the nasal bone is carried out using a 5-mm osteotome or straight guarded osteotome*.

A midline osteotomy of the nasal bone is carried out using a 5-mm osteotome. Depending upon the size of the nose, between two and five stab incisions are made along the lateral border of the nose and the bridge. Transcutaneous osteotomies are made using a 2-mm osteotome. Infracture is carried out like any other rhinoplasty procedure. If there is gross hypoplasia of the nasal bone, the infracture would not provide the necessary height in which case an onlay calvarial or costal cartilage graft is required.

Redraping

The skin is redraped; examination is carried out for residual asymmetry and irregularity. Crushed cartilage is used to overcome these problems.

Suturing

The nasal lining is repaired with 5-0 Vicryl suture and the columella skin with 6-0 Prolene sutures.

Splinting and dressing

Support tape is applied to minimize any chance of haematoma, following which a suitable thermoplastic nasal splint is applied. These procedures are exactly similar to any standard rhinoplasty operation. The difference here is placement of a suitable nostril splint, which should remain for a period of 3–6 months. This is a social embarrassment to some patients, but it must be used at night, at the very least.

Bilateral

The main difference is the columella shortening, bifid blunt nasal lobule and broad nasal bridge. The columella incision is designed to maximize the columella skin height (various modifications are shown in Figure 70.22a through d). The dissection is carried out as before, bilateral lower lateral cartilage mobilization is carried out as before, following which septal centralization is achieved. An intercrural graft is placed and stabilized with the medial crura to the desired height. Onlay conchal cartilage is placed and sutured as before (Figure 70.23).

Hump reduction is a rare event in the bilateral cleft. However, if needed, medial and lateral osteotomy is carried out with infracture. A spreader graft has a role to play in providing stability to the nasal septum and the nasal bridge. An onlay cartilaginous graft is placed if necessary and upper and lower lateral cartilages are sutured as before.

Nasal lining is extended to the inferior turbinate. The skin is repositioned and irregularities checked and corrected with crushed cartilage. The skin is repaired with 6-0 Prolene and the lining repaired with 5-0 Vicryl and the dressing is as before.

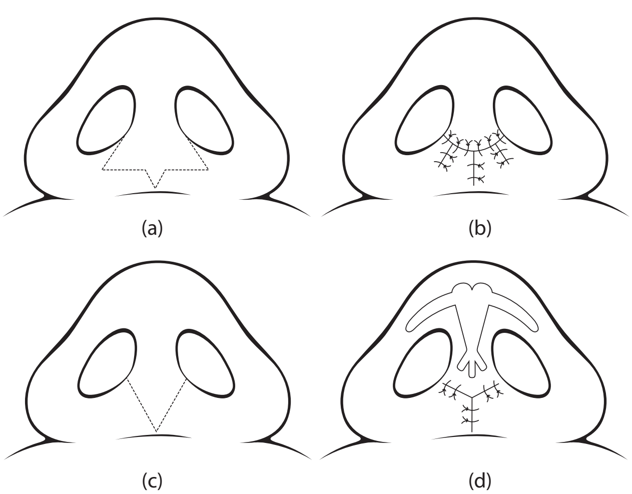


Figure 70.22 Various modifications of the columella incision designed to maximize the columella skin height.

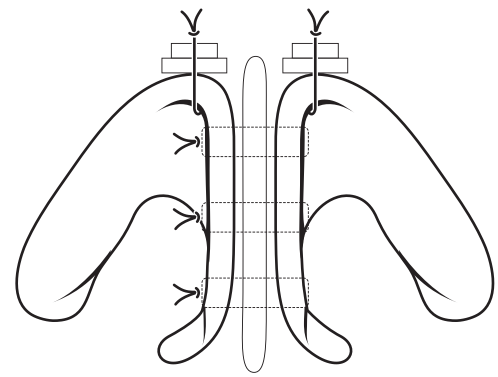


Figure 70.23 Intercrural graft held by mattress sutures. Onlay graft of the dome held by mattress sutures.

DEFINITIVE RHINOPLASTY

This is the final procedure in the journey of cleft patients.

Unilateral cleft rhinoplasty

The unilateral cleft lip nose is considered more difficult to treat than the bilateral cleft lip nose due to a lack of symmetry.

The problem list for the unilateral cleft/lip nose includes:

- Nasal tip asymmetry with the dome at the cleft side lower than the non-cleft side.
- The lower lateral crura at the cleft side is often crimped, deformed or hypoplastic.
- The nasal tip is often underprojected.
- The nasal tip may be wide as the lower lateral cartilages are spaced further apart.
- Asymmetry at the naso-alar groove, with depression at the cleft side.
- Horizontal or longer nostril at the cleft side.
- The alar rim at the cleft side is often lower than the non-cleft side.
- Soft tissue deficiency at cleft side with depressed nasal bony floor at the previous alveolar bone graft (ABG) site.

Technique

Reconstructing the bony defect at the cleft side

The facial skeleton as the framework for the face should be treated first in any craniofacial deformity before cleft rhinoplasty is performed. This holds true for both cleft and non-cleft patients. Patients who require maxillary advancement due to maxillary hypoplasia should ideally have the osteotomy first before rhinoplasty. Alternatively, the cleft lip rhinoplasty can be done simultaneously with the osteotomy. Bony depression at the previous alveolar bone graft side can be augmented with alloplastic material or autogenous material.

A block of contoured corticocancellous bone can be harvested from the mandible, calvarium or hip as required and secured to the pyriform rim defect as an onlay graft via an intra-oral circumvestibular incision. Two microscrews are used to secure the bone to the underlying bony base.

If a non-resorbable material is preferred, Medpor (porous polyethylene implants) can be fashioned and shaped to fit the defect as an augmentation material. The method of surgical access and means of securing the implant is the same as for bone grafts. To reduce the incidence of infected implant, the Medpor is soaked and impregnated with Gentamycin solution before final placement.

Incision and skeletonization

In cleft rhinoplasty, open rhinoplasty is preferred as it allows unparalleled access to the underlying aberrant nasal tip anatomy and dorsum. An inverted V-transcolumellar incision is used with bilateral marginal incisions. The nasal tip is carefully degloved and skeletonized. Very often, one will appreciate the difference in size and morphology between the lower lateral cartilage at the cleft side and the non-cleft side.

Dissection should be in a subperichondral plane along the upper lateral cartilage, followed by subperiosteal plane along the nasal bones.

Septal cartilage graft harvesting

The septum can be reached via a tip split technique. The fibrous attachment between the bilateral lower lateral cartilages is dissected to reach the septum. Subperichondal dissection is carried out and a piece of septal cartilage graft is dissected out leaving at least 10–12 mm of caudal and dorsal strut (Figure 70.24). To facilitate a wider exposure, part of the upper lateral cartilage can be separated from the nasal septum at the dorsal region.

Dorsal hump

For patients with dorsal humps, these can be removed as in any rhinoplasty. A cartilaginous hump can be excised with a blade while the bony hump is osteotomized and removed with a Rubin osteotome. The remaining rough edges can be smoothed out by rasping or by using a diamond bur (Figures 70.25 and 70.26).

Nasal bone infracture

Nasal infracture via endonasal or percutaneous osteotomies can be done to close the open roof defect and realign the nose if it is deviated.

For the deviated nose, the bony septum should also be mobilized and straightened.

Nasal tip surgery

There are a few tip grafting techniques that are useful in cleft lip rhinoplasty. They are as follows:

1. Extended septal graft (Figure 70.27)
2. Columellar strut (Figure 70.27)
3. Onlay graft (Figure 70.28)
4. Alar Batten graft (Figure 70.29)

An extremely useful method in acquiring additional nasal projection is the extended septal graft technique. The septal cartilage graft is sutured to the caudal end of the septum with 5-0 PDS sutures, projecting in a caudal direction beyond the nasal septum. This allows correction of the nasolabial angle from an obtuse angle to 90°.

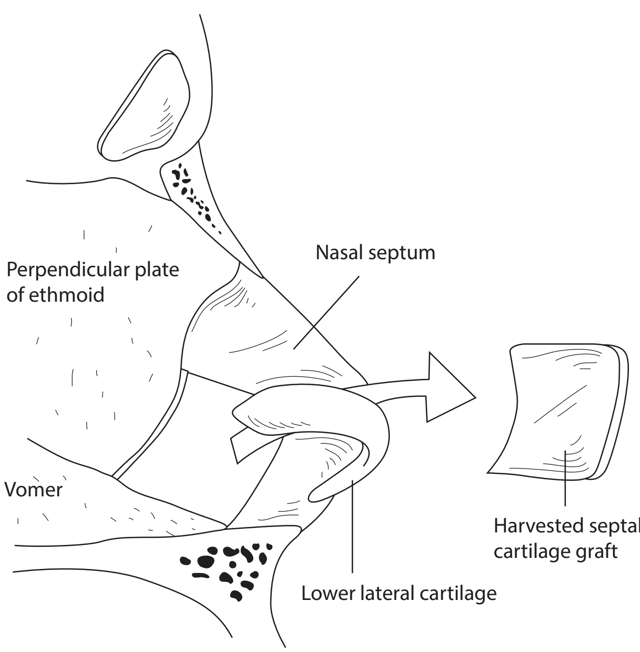


Figure 70.24 Septal graft is harvested from the septum, leaving 10–12 mm of dorsal and caudal strut.

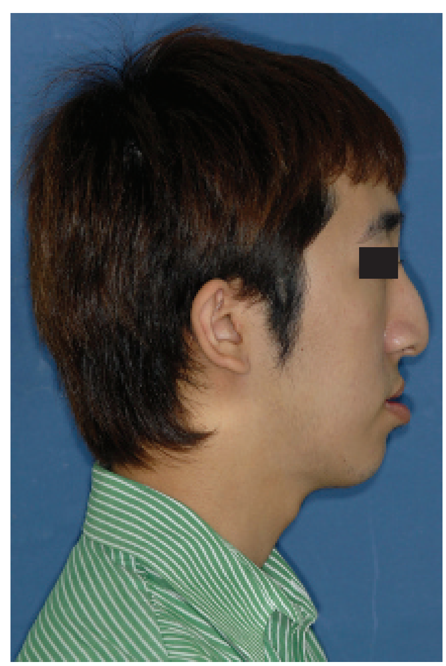


Figure 70.25 Left-sided unilateral cleft lip nasal deformity (pre-operative).

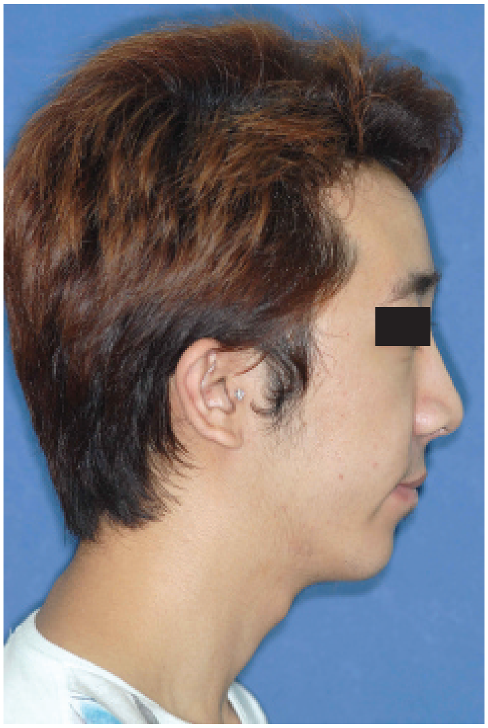


Figure 70.26 Hump reduction with columellar strut and onlay grafts (post-operative).

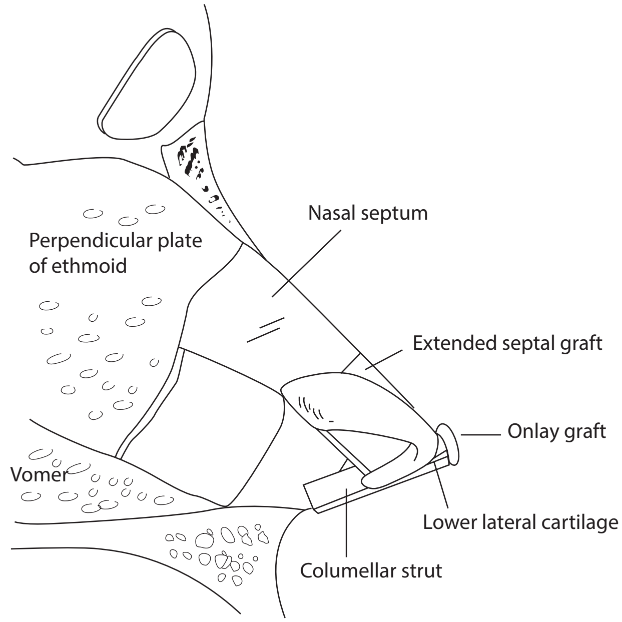


Figure 70.28 The nasal projection is directed in a caudal, anterior direction by the extended septal graft and columellar strut. Placement of an onlay graft at the nasal tip will further increase nasal projection, mask some asymmetry of the nasal tip and form a more defined nasal tip.

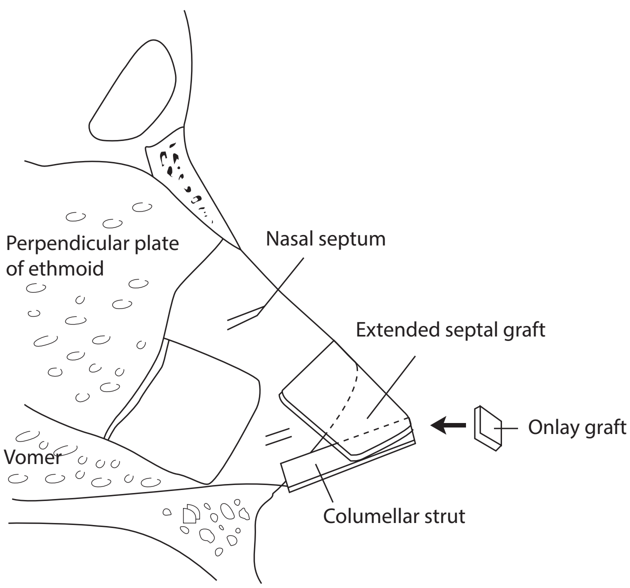


Figure 70.27 Extended septal graft is fashioned from the harvested septal graft. It is sutured to the caudal end of the septum. It can be further reinforced by a columellar strut.

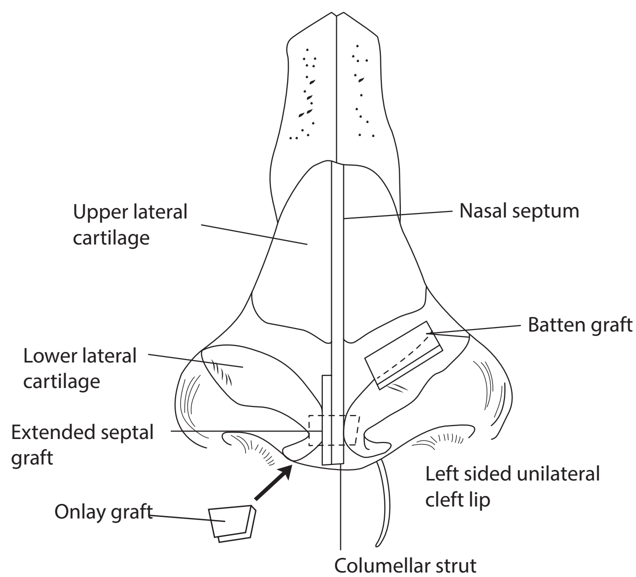


Figure 70.29 Illustration showing extended septal graft sutured to the caudal end of the septum, columellar strut, left-sided Batten graft and an onlay graft.

For increased strength and height, the nasal tip is further 'propped up' with a columellar strut. The columellar strut should be sutured to the extended septal graft. The dome at the cleft side can be lifted to the same height as the dome of the non-cleft side and sutured to the extended septal graft and columellar strut. Onlay grafts can be sutured on top of this to increase the nasal tip height. This helps to mask some of the asymmetry in the nasal tip. Residual asymmetry due to the hypoplastic nature of the lower lateral cartilage at the cleft side can be camouflaged with alar batten graft. The best sources of cartilage grafts are either septal or conchal cartilages. Rib cartilage grafts are useful when strong projections are needed and are used for extended septal grafts and columellar struts.

Various suturing techniques are employed to reduce the nasal tip width. These include transdomal sutures, interdomal sutures and intercolumellar sutures.

Shallow nasal bridge

This is a main problem among the oriental population. This can be augmented with either alloplastic material or autogenous cartilage graft.

Alloplastic material

Gore-Tex (expanded polytetrafluoroethylene) is a commonly used material. This can be fashioned into a dorsal graft and placed in the subperichondral and subperiosteal pocket to augment the nasal bridge. Sheets of Gore-Tex of 2-mm thickness can be stacked to the required height and secured with 5-0 PDS sutures. To reduce the incidence of infected implants, the Gore-Tex is soaked in Gentamycin solution before final placement. The graft has to be further shaped to ensure smooth continuity between the implant and the radix and bridge of the nose.

Costochondral (RIB) graft

A source of autogenous cartilage graft is the costochondral cartilage. The fifth, sixth or seventh rib can be harvested via an inframammary incision. The obtained rib graft can then be fashioned to a dorsal graft of the appropriate height and length. This can be placed in the subperichondral and subperiosteal pocket (Figures 70.30 and 70.31).

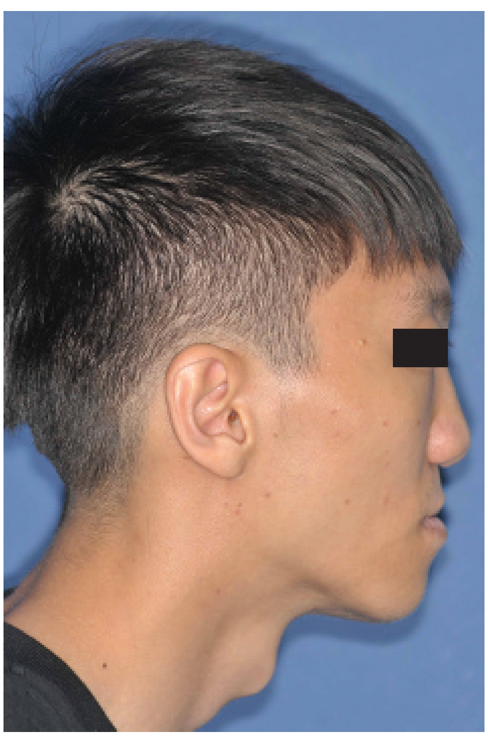


Figure 70.30 Left-sided unilateral cleft nasal deformity.

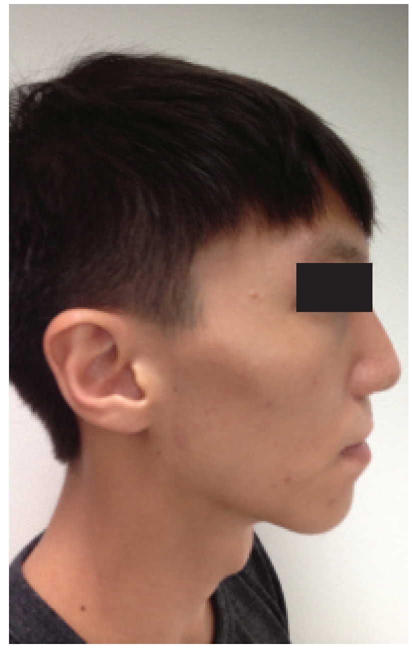


Figure 70.31 Post-dorsal augmentation with rib cartilage, extended septal graft and columellar strut.

Alar base

Alar base reduction can be done together with percutaneous alar cinch with 3-0 non-resorbable sutures. Differential reduction may need to be done, as the alar width at the cleft side may be wider than the non-cleft side.

Vestibular mucosa excision

Excess vestibular mucosa at the cleft side can be trimmed selectively to restore a semblance of nostril symmetry.

Closure

Skin closure by 6-0 Prolene and mucosal closure with 5-0 Vicryl sutures.

Bilateral cleft lip rhinoplasty

The problems list for bilateral cleft lip nose includes the following:

- Broad nasal bridge
- Depressed nasal tip with decreased nasal projection
- Short retracted columella
- Wide amorphous nasal tip
- Wide alar base

One does not have to deal with the asymmetry of the unilateral cleft lip nasal deformity in bilateral cleft lip rhinoplasty. The aim of the surgery is to achieve increased nasal tip projection, narrow the nasal bridge, the nasal tip and the alar base. Incision and skeletonization

techniques are the same as that for the unilateral cleft lip nasal deformity.

Narrowing of the nasal bridge

Although hump reduction is rare, infracture of the nasal bone is still carried out as it allows narrowing of the nasal bridge. This can be performed with medial and lateral nasal osteotomies and results in sharper nasofacial angles. Augmentation of the dorsum with alloplastic implants such as Gore-Tex or rib grafts helps in two ways. It augments the dorsum of the shallow bridge and simultaneously creates the illusion of a narrow nasal bridge.

Nasal tip surgery

The bilateral cleft lip nasal deformity presents with a shortened columella. Nasal tip projection can be increased with a columellar strut and this can be further reinforced with extended septal graft if needed. Instead of conchal and septal grafts, rib grafts may be needed to form the strong underlying architecture. The wide nasal tip can be narrowed with transdomal sutures and interdomal sutures using 5-0 resorbable sutures on a round bodied needle. Further definition and projection of the nasal tip can be achieved with onlay grafts.

Alar base

Alar base reduction can be done together with percutaneous alar cinch.

Closure is as described in unilateral cleft rhinoplasty.

Competency should be obtained in the standard aesthetic rhinoplasty prior to engaging in cleft rhinoplasty procedures.

SUGGESTED READINGS

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Malek R. Nasal deformities and their treatment in secondary repair of cleft lip patients. A clinical study of 175 cases. *Scand J Plast Reconstr Surg*. 1974; 8: 131–141.

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SECTION X

CRANIOFACIAL SURGERY

71

Segmental surgery of the jaws

PAUL JW STOELINGA

CONTENTS

PRE-OPERATIVE ASSESSMENT

The need for segmental surgery, with the intention to align the dentoalveolar arches, has greatly been reduced, since it is now widely accepted that orthodontic treatment should be part of the treatment plan in patients with dentofacial deformities. Alignment of teeth and elimination of dentoalveolar compensation is usually achieved by orthodontic treatment alone, yet there still are indications for segmental surgery and they will be discussed for each separate osteotomy. In general, however, segmental osteotomies carried out in the dentate area require enough available space for these osteotomies to be performed safely without damage to the periodontal apparatus. This implies that when segmental surgery is contemplated, this aspect should be carefully considered in the treatment plan so that spaces are created in the dental arches.

This advice is particularly relevant for mandibular segmental surgery because the mandibular bone is usually more dense when compared to the maxilla and, therefore, less abundantly vascularized. In general, a diastema of 5 mm, allowing for approximately 2 mm of septal bone to be attached to the root of the tooth next to the osteotomy, is considered to be safe.

ANTERIOR MAXILLARY SEGMENTAL OSTEOTOMY

History

The first account of an anterior maxillary segmental osteotomy (AMSO) was probably from Cohn-Stock in 1921,[1] but a single stage set-back osteotomy through a vestibular approach was first described by Wassmund in 1926.[2] In 1962, Wunderer presented an important improvement of Wassmund's technique in that he recommended a predominantly palatal approach, which simplified the procedure. In 1980, Bell introduced the concept of the 'down-fracturing' in which the anterior segment is approached through a horizontal vestibular incision.[3]

Principles and indication

The main consideration for the AMSO is to reposition and fix the fragment in the desired position without jeopardizing the vascular pedicle. The vascular pedicle is either predominantly buccal or palatal. In either situation, care should be taken not to impair the blood supply by inadvertent cutting of the important vessels or by stretching or folding of the mucoperiosteal flap that contains the vascular pedicle.

The anterior fragment may be moved upwards, downwards, rotated and set back. An additional mid-line osteotomy allows for expansion or elimination of a central diastema. Most importantly, however, this allows for correct positioning of the canines by the rotation of both anterior fragments slightly by pulling the canines down. At present, this osteotomy is mainly carried out to correct an extremely reversed curve of Spee by intruding the anterior segment, i.e. in Class II division 2 anomalies. For this reason, the Wunderer approach is to be preferred.

Techniques

Wunderer technique

Two vertical, vestibular incisions are made with a distal slant, to provide a maximum buccal, soft-tissue pedicle (Figure 71.1). The mucoperiosteum is gently elevated to reach the nasal aperture. A periosteal elevator or small Langenbeck retractor is used to retract the mucoperiosteal flap, but care should be taken not to strip off the gingival attachments around the anterior teeth. With a short Lindemann burr, a bone cut is made from the nasal aperture slightly curved towards the alveolar crest (Figure 71.2). Care should be taken not to damage the periapical area of the canines. It is recommended that a 5 mm margin above the apices of these teeth be left in order to avoid permanent neurovascular damage. The cut through the alveolar portion may be completed at this stage. Attention is then directed towards the palate and an anteriorly curved incision is made through the palatal mucosa (Figure 71.3). The mucoperiosteum is elevated posteriorly and the palatal cut is made connecting both alveolar cuts (Figure 71.4). At this stage, attention should be paid to the position of the nasal tube and cuff as they can easily be damaged during this procedure. After completion of the bone cuts, the anterior segment can be rotated upwards, thereby dislocating the cartilaginous nasal septum from the nasal crest. A chisel may then be used to cut the nasal

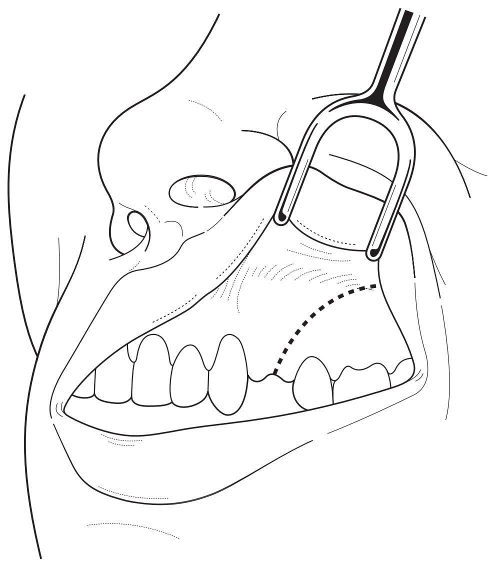


Figure 71.1 Incision is curved backwards to allow a broad, buccal pedicle.

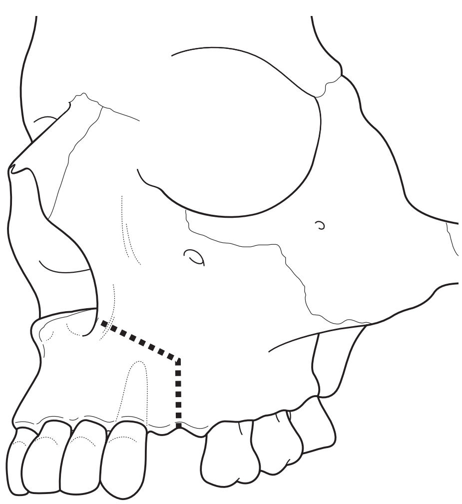


Figure 71.2 Curved bone cut running from the nasal aperture to the alveolar crest. A 5-mm margin is left with regards to the apex of the canine tooth.

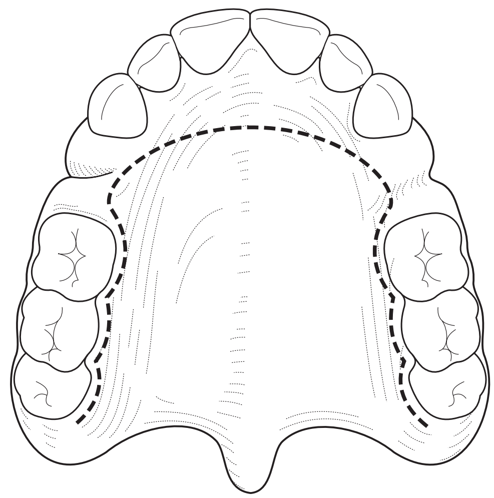


Figure 71.3 Anteriorly curved incision made in the palate. Posterior of the line of the supposed osteotomy, the cut may be made in the gingiva to allow reflection of the flap.

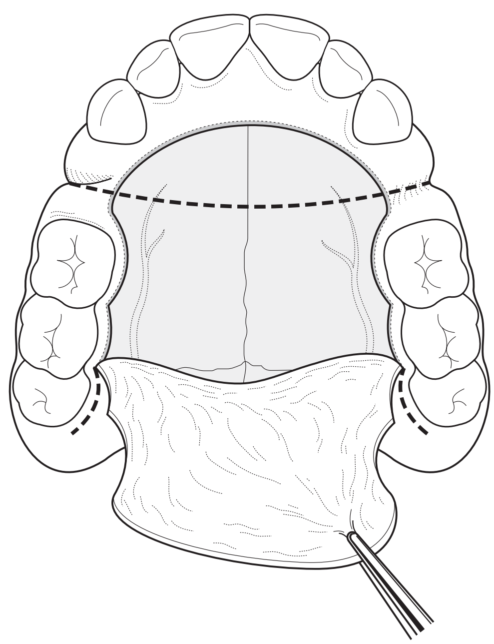


Figure 71.4 The palatal bone cut running straight over the palate connecting the two alveolar cuts.

septum in a more controlled fashion once the fragment is beginning to rotate.

The fragment may be rotated all the way up, just pedicled to the vestibular mucoperiosteum (Figure 71.5). In this way, excellent access is obtained for trimming the bony interferences that exist when the fragment is to be set back or intruded. A well-irrigated acrylic burr is ideal to reduce the bony margins, particularly on the palatal side and the paranasal buccal bone plates. The nasal spine should be reduced, if necessary, for which a bone rongeur may be used.

A mid-line osteotomy is often necessary. This allows for widening of the fragment and better positioning of the canines in the dental arch. A thin Lindemann burr is best used to start approximately 5 mm away from the palatal gingival margin and continue all the way through the segment towards the palatal cut. Separation is achieved by gently wiggling with an osteotome; this causes fracturing of the interdental septum and buccal plate (Figure 71.6). This way, the least possible damage is inflicted to the periodontal apparatus. If elimination of a central diastema is required, the interdental bone should be reduced from a palatal approach with a short Lindemann burr.

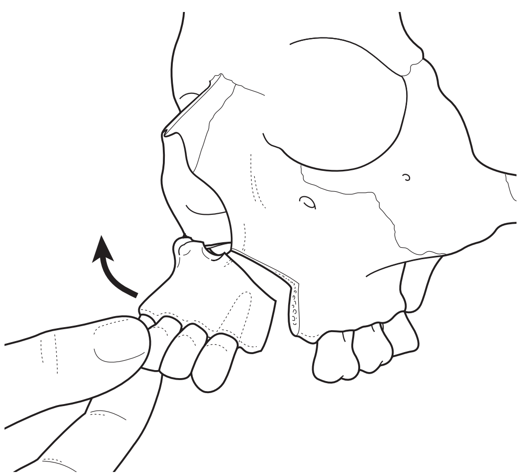


Figure 71.5 Anterior fragment rotated upwards still pedicled to buccal mucoperiosteum.

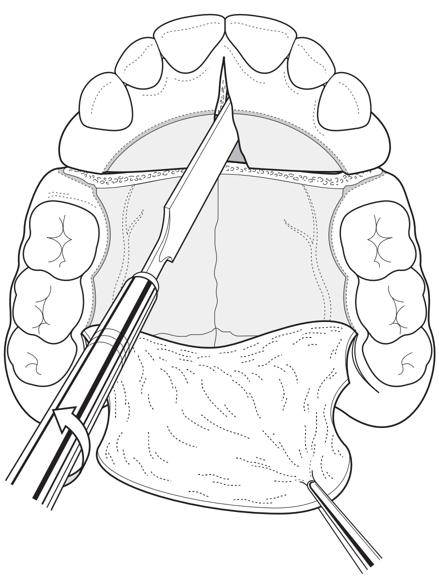


Figure 71.6 After a groove is made with a thin Lindemann burr, an osteotome is used to 'fracture' the buccal cortical plate by wiggling.

WASSMUND TECHNIQUE

The Wassmund approach also begins with two vertical vestibular incisions that may be curved anteriorly to expose the nasal aperture. The bone cuts are made as described for the Wunderer technique. On the palatal side, bilateral marginal gingiva incisions are made from the lateral incisor to the second premolar, after which the palatal mucosa is elevated from the bone in a tunnelled fashion (Figure 71.7). The palatal bone cut is made through the buccal cuts with a long Lindemann burr. This procedure is essentially carried out blindly. The separation from the nasal septum is achieved through a small vertical mid-line incision in the buccal vestibule. The nasal spine is exposed and the septum cut from the nasal crest with a forked chisel.

It is the appropriate reduction of bone on the palatal side that makes this procedure a less attractive alternative. This, again, is to be carried out blindly with the obvious risk of taking away too much bone. Mid-line splitting, if necessary, should be done from the buccal side with a thin fissure burr and thin osteotome. For this reason, a small vertical incision is made over the nasal spine in the vestibule. The spine is exposed by limited subperiosteal dissection.

DOWN-FRACTURING TECHNIQUE

For the down-fracturing technique, a horizontal vestibular incision is made extending at least one tooth distal to the proposed osteotomy on both sides. The mucoperiosteum is reflected to expose the nasal aperture, whilst the alveolar crest at the side of the osteotomy is also carefully exposed.

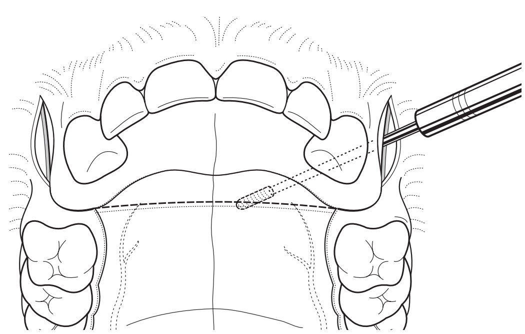


Figure 71.7 The palatal bone cut is made with a long Lindemann burr after the palatal mucosa, which is still attached to the anterior fragment, has been lifted.

The bone cuts are made as in the Wassmund technique but the vertical cuts are used to gain access to the palatal bone. The palatal cut is completed with a thin tapered fissure burr or 4 mm osteotome. During this manoeuvre, the palatal mucosa should not be damaged since this will be the sole vascular pedicle once the fragment is down fractured. When the anterior fragment is down fractured, the bone can be trimmed to fit the new position.

Fixation

If no posterior segmental osteotomies are carried out, fixation is relatively simple. A prefabricated acrylic splint, reinforced with a steel wire with which loops are made, is used to stabilize the fragments. The anterior fragment is manoeuvred into place, after which the splint is first fixed to the posterior teeth using pull wires, that are fed through the loops in the wafer (Figure 71.8). Once this is done, pull wires should be used to first pull the canines into the splint, and if necessary, followed by the central incisions. Since a tendency exists for the fragment to be slightly rotated upwards when pushed backwards, the canines tend to be in supraposition. This undesirable effect can be counteracted by a mid-line split and the use of canine pull wires. To secure the position of the anterior segment(s), two four-hole miniplates can be used to fix the fragment (Figure 71.9).

The acrylic splint may be removed in a few days if the patient still has orthodontic brackets. A rigid arch wire will then usually suffice to keep the teeth in the proper position. Intermaxillary fixation is never necessary and is not to be recommended. In case, the anterior segmental osteotomy is combined with posterior segmental osteotomies, the posterior fragments should be stabilized first with an acrylic splint, temporary IMF and miniplates. Once secured, the anterior fragment can be stabilized with a four hole microplate. The incisions are closed using 3/0 sutures.

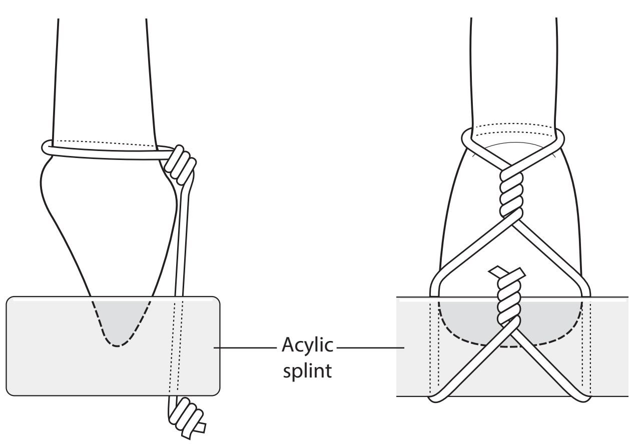


Figure 71.8 Acrylic splint secured to the posterior teeth first using pull wires. Pull wires are also used to fix the anterior fragment in the splint. These wires are twisted around the canines and then tightened to the splint.

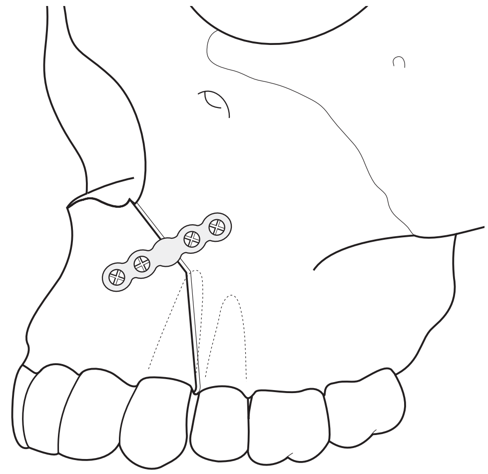


Figure 71.9 Four-hole microplate securing anterior fragment to the posterior maxilla, above the level of the apices.

Post-operative care

Apart from some swelling apparent for a few days, hardly any complications can be expected. However, when intrusion is the main purpose of the procedure and the palatal mucosa is left intact (Wassmund or down-fracturing technique), it is recommended that the colour of the buccal gingiva is carefully checked. A bone step at the site of the palatal osteotomy may cut off the blood supply and, thus, endanger the viability of the anterior segment.

POSTERIOR MAXILLARY SEGMENTAL OSTEOTOMY

History

The posterior maxillary segmental osteotomy (PMSO) was introduced in 1954 by Schuchardt as a two-staged procedure to correct anterior open bite.[4] In 1960, Kufner described a one-stage modification.[5] Several modifications of the PMSO have been described with either horizontal or vertical buccal incisions, a direct or transantral approach to the palate and varying degrees of exposure of the palatal bone before osteotomy. In 1972, West and Epker provided an extensive review, emphasizing the versatility of this procedure.[6]

Principles and indications

As in the AMSO, special attention should be paid during the whole procedure to the buccal gingiva to maintain adequate blood supply to the fragment. Inadvertent tearing of the buccal or palatal mucoperiosteal flap may jeopardize the vitality of the segment.

Typical indications include anterior skeletal open bite treated by bilateral PMSOs with intrusion of the segments.

Although at currently this deformity is often treated by a one-piece Le Fort I tilting and intrusion osteotomy, the indication is still valid, particularly in patients with a steep sella-nasion-A (SNA) angle, because tilting of the whole tooth-bearing maxilla tends to cause an obtuse nasolabial angle.

Extrusion, widening and narrowing of the posterior arch are also possible with this technique and vertical movements are often combined with transverse movements. One of the best applications is advancement and rotation of the lesser segment in unilateral cleft lip and palate (CLP) patients or the posterior segments in bilateral CLP patients. The PMSO allows for reconstruction of an uninterrupted arch form in many of these patients, simultaneously with grafting of the alveolar cleft.

In general, elimination of edentulous spaces in the arch can be achieved by advancing the posterior segment.

Technique

A vertical incision is made in the buccal mucoperiosteum of the interdental area (Figure 71.10) and carried over to the palatal side. With the alveolus exposed by reflection of the mucoperiosteum, the bone cut is made with a fine tapering fissure burr (short Lindemann). Bucally, submucoperiosteal tunnelling is carried posteriorly towards the tuberosity. A flat, malleable retractor is placed under the buccal pedicle with care taken not to tear off the attached gingiva. The lateral, horizontal bone cut is made with a long Lindemann burr in an 'inside to outside fashion'. It is first placed into the antrum at the uppermost point of the vertical osteotomy, approximately 5 mm above the apices of the posterior teeth (Figure 71.11). This distance is considered to be safe with regards to the neurovascular regeneration of the pulp of the teeth involved. The cut can be completed almost to the tuberosity, the last millimetres finished with a 4 mm osteotome.

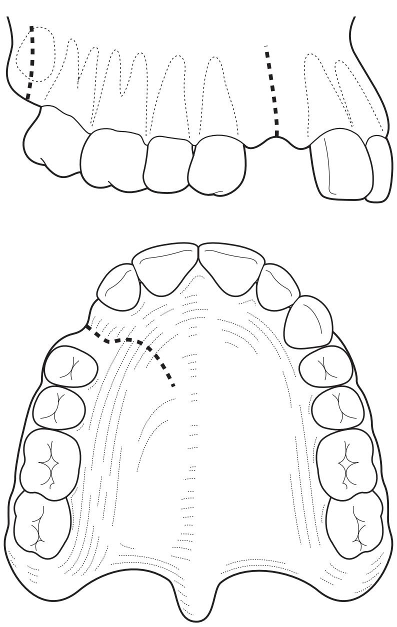


Figure 71.10 Position of buccal and palatal incisions for posterior segmental osteotomy.

The palatal osteotomy can be performed with a fine tapering fissure burr or osteotome directly through the posterior palatal mucoperiosteum, without direct exposure of the bone. The aim is to place the bone cut at the junction of the alveolus with the horizontal palatal process, above the root apices and lateral to the greater palatine artery. With a 4 mm osteotome angled at 45° to the vertical plane, a series of punctures into the antrum can be made, after which the cut is completed with a 10 mm Teflon-handled osteotome. This way the palatal mucoperiosteum still maintains a pedicle to the soft palate, which contributes to the blood supply to the segment (Figure 71.12). The final step is the posterior osteotomy through the tuberosity region which is the same as described for the Le Fort I osteotomy.

Mobilization is achieved by rotating the osteotome in the palatal osteotomy and by forward mobilization with a curved osteotome in the tuberosity region (Figure 71.13).

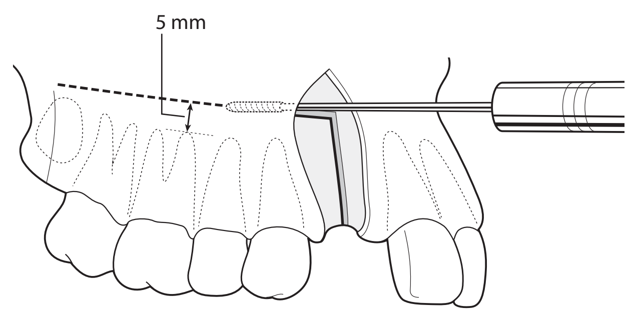


Figure 71.11 Bone cut made in a tunnelled fashion approximately 5 mm above the level of the apices.

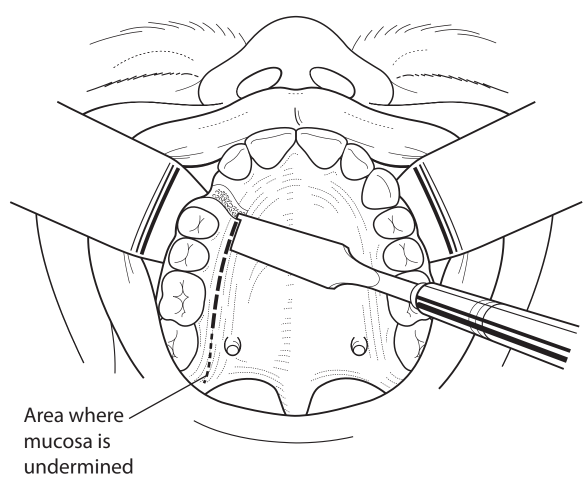


Figure 71.12 Palatal bone cut made at the junction of the alveolar process and the palate. The cut should be made lateral to the greater palatal foramen. The mucosa in the posterior palate can be left intact by guiding the osteotome under the mucosa and completing the bone cut in a tunnelled fashion.

Fixation

The segment(s) are moved into the desired position and fixed with the aid of an acrylic, prefabricated splint and pull wires much the same as described for the AMSO. Once in position and fixed, a mini- or microplate can be used to provide additional stabilization (Figure 71.14). Due to the limited access, usually only one plate on each side can be placed. The acrylic splint should therefore be maintained for a period of 6 weeks, but IMF is not necessary. The incisions are closed with 3/0 sutures.

Post-operative care

The same considerations are applicable as for the Le Fort I osteotomy with regards to swelling and possible post-operative bleeding. There are no special aspects to be considered apart from occlusal factors.

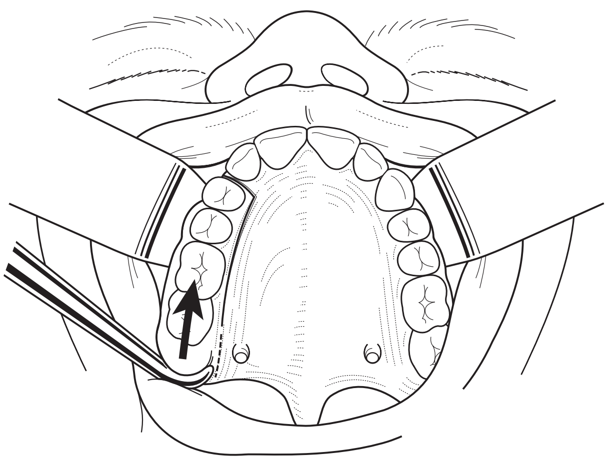


Figure 71.13 A curved osteotome is used in the tuberosity area to mobilize the segment and also to manoeuvre it forwards.

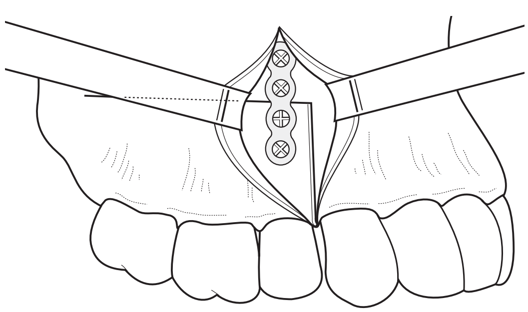


Figure 71.14 Mini- or microplate can be used to fix the posterior segment to the remaining maxilla.

Application of posterior maxillary segmental osteotomy in cleft patients

The PMSO is extremely suitable for advancing and rotating the lesser fragment in unilateral CLP patients or for repositioning both posterior fragments in bilateral CLP patients. This can be done whilst the cleft is simultaneously grafted. For this purpose, an incision is made around the cleft extended upwards (Figure 71.15). The soft tissue in the cleft is mobilized and pushed upwards to form the nasal layer. The vertical incision is used to reflect the buccal mucoperiosteum, just as described for the PMSO. The palatal osteotomy is made lateral to the scar tissue that is usually present in the palatal cleft. After the tuberosity split, the fragment is mobilized as for a non-cleft case.

At this stage, the nasal layer is closed after appropriate trimming of the redundant scar tissue. The segment is then advanced and rotated or brought downwards as required, and fixed with the use of an acrylic splint and one four-hole miniplate (Figure 71.16). Once stabilized the narrowed alveolopalatal cleft is grafted with autogenous corticocancellous bone, and the palatal and buccal mucosa can be closed with 3/0 sutures because the advancement has approximated the soft tissues. This technique usually corrects the paranasal depression often seen in cleft palate patients and considerably improves the existing asymmetry of the alar base (Figure 71.17). Long-term follow-up studies have shown that the technique provides predictable and stable results.

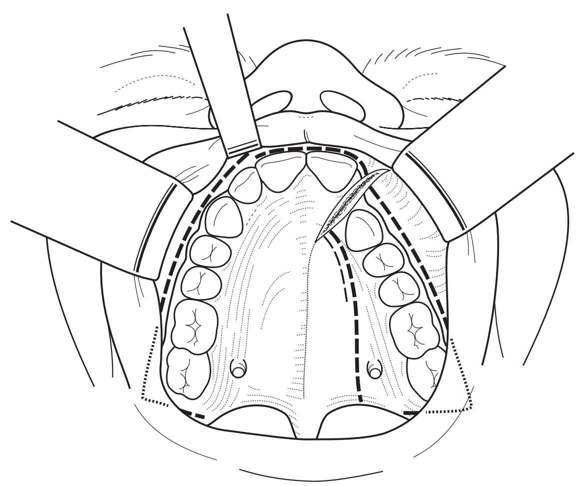
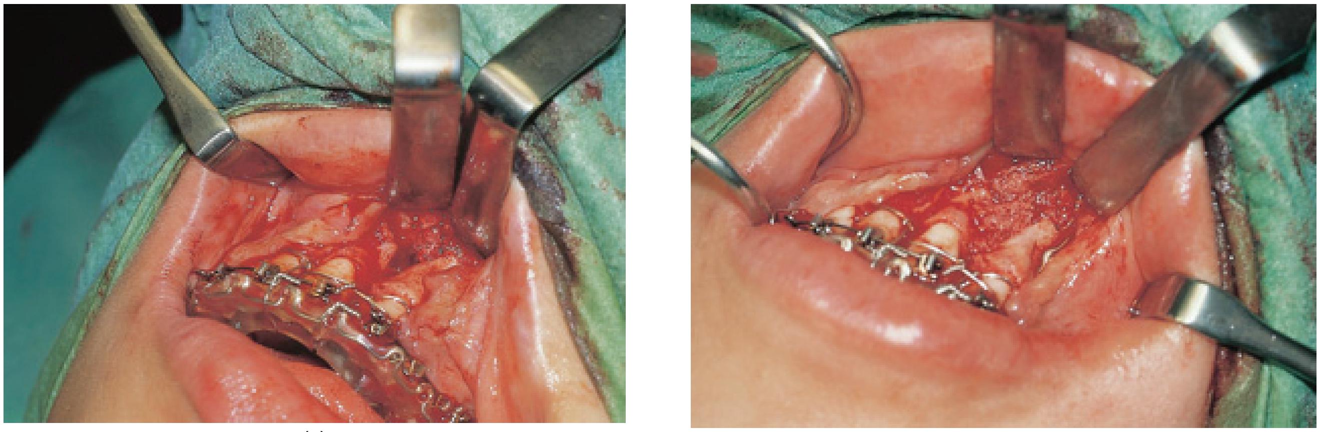
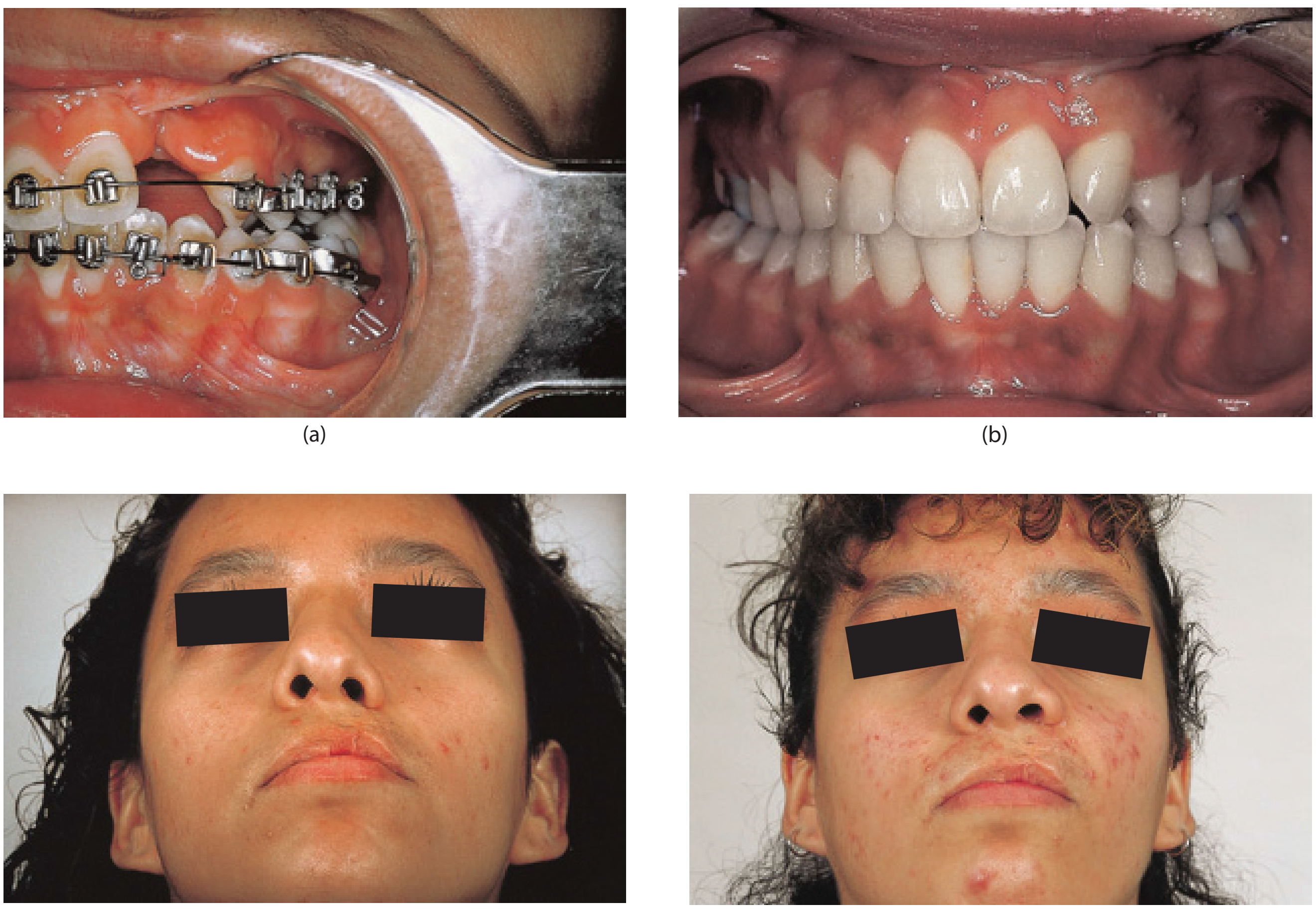


Figure 71.15 Segmental osteotomy of the lesser fragment in patients with unilateral cleft lip and palate. The major fragment can be mobilized using the Le Fort I technique.



(a) (b)

Figure 71.16 (a) Lesser fragment advanced and fixed in the splint with wires. (b) Alveolopalatal cleft is grafted with particulate autogenous bone.



(a) (b) (c) (d)

Figure 71.17 Pre-operative (a and c) and post-operative (b and d) situation in patient with left-sided unilateral complete cleft. Note elimination of edentulous space and alignment of segment. Symmetry of the alar base has been achieved by advancing the lesser fragment (c and d).

ANTERIOR MANDIBULAR SUBAPICAL OSTEOTOMY

History

The first description of an anterior subapical mandibular osteotomy was by Hullihen in 1849.[7] However, in 1942, Hofer made this procedure popular by recommending its use for dentoalveolar set-back as well as advancement.[8] In 1959, Kar advocated this osteotomy to treat anterior skeletal open bite by interposition of a bone graft taken from the lower border of the mandibular symphysis.[9]

Vertical bone cuts are made in the areas designated and they are connected by a horizontal bone cut. These bone cuts are made with a tapered fissure burr and, if possible, carried just through the lingual cortex. The horizontal bone cut should be at least 5 mm away from the apices of the roots of the anterior teeth (Figure 71.18). A 4 mm osteotome may be used to finish the osteotomy. If the segment is to be brought down, a strip of bone should be removed so as to allow the segment to fit the new position. A prefabricated acrylic splint helps to position the segment correctly in the desired position.

Fixation

The anterior segment, once manoeuvred into place, is ideally fixed with miniplates. The four-hole plates are bent to fit the contour and placed in the corners of the box. If necessary, an additional plate may be placed in the middle of the horizontal bone cut. If orthodontic treatment is carried out, the wafer does not need to be fixed. Instead, a rigid orthodontic arch wire should be inserted which will be sufficient to maintain the position of the front teeth. In cases where no orthodontic treatment is planned, an arch bar or acrylic splint fixed to the teeth will be necessary to maintain the position.

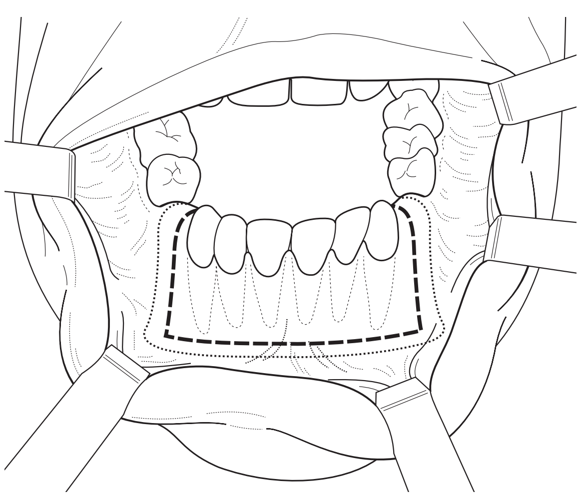


Figure 71.18 Incision in the interdental areas carried out in the vestibule to approach the anterior subapical area and bone cuts for the subapical anterior mandibular osteotomy.

Principles and indications

The anterior subapical mandibular osteotomy is, at present, mainly used to level an extruded anterior dentoalveolar part. In principle, however, movements in all directions are possible, including forwards and backwards and even upwards if the gap is grafted. It is also possible to correct asymmetries.

Its vascularization is completely dependent on the lingual mucoperiosteum–muscle pedicle and therefore attention should be paid during the whole surgery not to tear this pedicle. This is particularly relevant when relatively large movements are planned.

Technique

Vertical incisions are made in the mucoperiosteum of the interdental area and these are joined up by a vestibular incision that is carried out into the buccal vestibule (Figure 71.19). After subperiosteal dissection, the whole buccal side of the chin is exposed and the flap pulled downwards with a chin retractor as described for the genioplasty. Vertical bone cuts are made in the areas designated and they are connected by a horizontal bone cut. These bone cuts are made with a tapered fissure burr and, if possible, carried just through the lingual cortex. The horizontal bone cut should be at least 5 mm away from the apices of the roots of the anterior teeth. A 4 mm osteotome may be used to finish the osteotomy. If the segment is to be brought down, a strip of bone should be removed so as to allow the segment to fit the new position. A prefabricated acrylic splint helps to position the segment correctly in the desired position.

Fixation

The anterior segment, once manoeuvred into place, is ideally fixed with miniplates. The four-hole plates are bent to fit the contour and placed in the corners of the

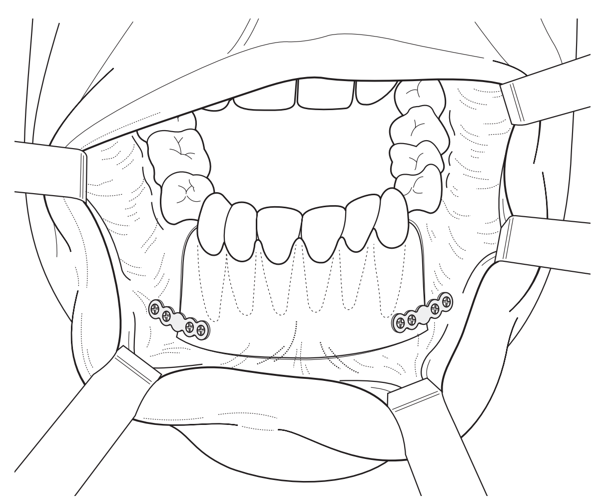


Figure 71.19 Fixation of the anterior segment with two four-hole miniplates.

box (Figure 71.19). If necessary, an additional plate may be placed in the middle of the horizontal bone cut. If orthodontic treatment is carried out, the wafer does not need to be fixed. Instead, a rigid orthodontic arch wire should be inserted which will be sufficient to maintain the position of the front teeth. In case no orthodontic treatment is planned, an arch bar or acrylic splint fixed to the teeth will be necessary to maintain the position.

KÖLE TECHNIQUE

In 1959, Köle recommended the use of this osteotomy to close an anterior open bite whilst the gap was grafted with bone taken from the lower border. This author advises strongly against this method because this will most likely change the contour of the chin in an unacceptable manner. Detachment of the periosteum and muscles and resection of the rounded inferior fragment will create a square 'fleshy chin' that is aesthetically not pleasing. If this technique is selected, the interpositional graft should be harvested from another location.

Post-operative care

This osteotomy does not usually create unforeseeable problems although, as in genioplasties, severe haemorrhage in the floor of the mouth may be encountered. This is due to damage to the vessels located in the genioglossal muscle. Ice packs and positioning of the patient in an upright position are supportive measures to be taken. Apart from occlusal factors, no other aspects need be considered.

Top tips

In the Wunderer technique, the vertical incisions must incline posteriorly to maintain a good blood supply to the anterior segment.

- It is important to avoid any damage to the periodontal ligaments of the teeth adjacent to the osteotomy cuts.
- A very fine osteotome rather than a bur should be used to complete the bone cuts.

A preformed acrylic splint wired to the teeth is usually sufficient to immobilize the segments.

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Orthognathic surgery of the mandible

PAUL A JOHNSON

CONTENTS

INTRODUCTION

Orthognathic mandibular surgical techniques are used mainly to correct mandibular prognathism and retrognathia. In addition, lower facial asymmetries, anterior open bites and post-traumatic malocclusions can be rectified. They can be used alone as single-jaw procedures or in combination with midface procedures as a bimaxillary procedure.

They are widely used for the correction of dentofacial deformities and indications include malocclusions causing masticatory difficulties, temporomandibular dysfunction, sleep apnoea and unaesthetic appearance with its attendant psychosocial effects.

Orthodontic preparation for surgery is usually required to align, decompensate and coordinate the dental arches. Ideally, treatment planning should be performed jointly between the surgeon and orthodontist to clearly identify treatment goals. Orthodontic preparation time varies but usually requires approximately one year of fixed appliance therapy. Post-surgical orthodontic detailing normally takes about 6 months.

The most frequently used mandibular techniques are the bilateral sagittal split osteotomy (BSSO) and the horizontal genioplasty. Other techniques, such as the vertical subsigmoid, inverted-L and C-osteotomies, although they still have some adherents, are infrequently indicated and relatively rarely performed.

BILATERAL SAGITTAL SPLIT OSTEOTOMY

The BSSO was first described in 1957 by Trauner and Obwegeser and subsequently modified by DalPont, Hunsuck and Epker.[1–4]

Its main advantage is its versatility. Mandibular advancement, setback and rotation can all be achieved. An anterior open bite can be corrected by anticlockwise rotation. It is carried out by an intraoral approach avoiding external scarring. Direct fixation of the osteotomy sites by miniplate or bicortical screw osteosynthesis is easily achieved, thereby negating the need for post-operative intermaxillary fixation with its associated safety and patient comfort implications.

Major complications are rare. Excessive haemorrhage is uncommon, although the facial vessels are at risk when making the buccal bone cut unless adequately protected by a retractor. There is a risk of distraction of the condyle when advancement of the mandible is carried out with consequent incorrect occlusion which may only be recognized post-operatively, necessitating an early return to the operating theatre for revision. The most frequent complication and major risk of the BSSO, however, is damage to the inferior dental nerve. Reported incidences vary, but it is common in the immediate post-operative period. Permanent anaesthesia is rare, however, with recovery usually occurring over a period of weeks or months. Finally, unfavourable fracture at the osteotomy site can result in a 'bad split'. This is largely technique dependent. Ideally, lower third molars should be removed at least 6 months before surgery to minimize the risk of this occurring.

SURGICAL TECHNIQUE

Incision

The incision is made down the external oblique ridge down the lateral mandibular ridge and deepened down

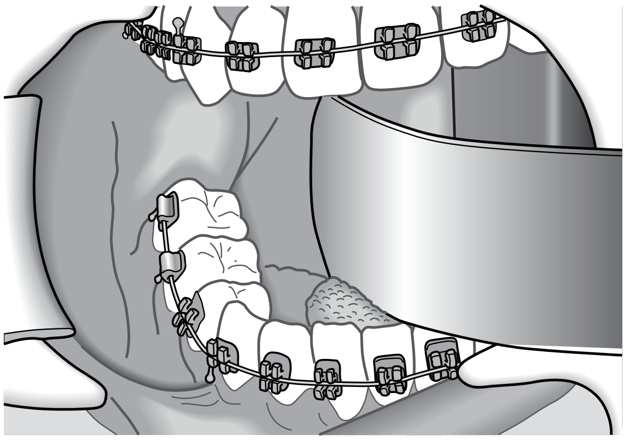

Figure 72.1 Incision line on the external oblique ridge.

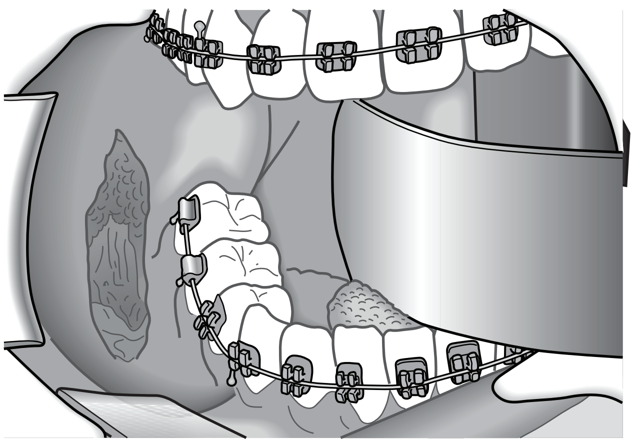

Figure 72.2 Incision will be extended down to bone.

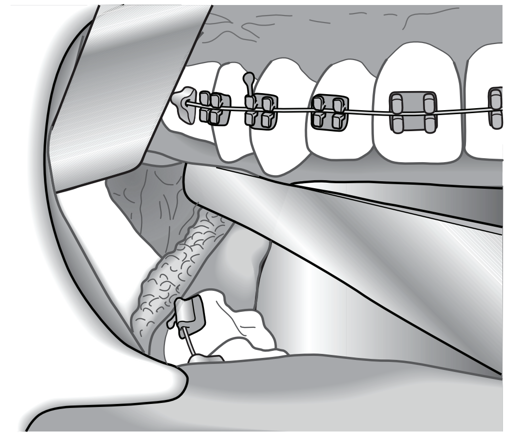

Figure 72.3 Periosteal elevator being used to expose the lingual aspect of the ramus.

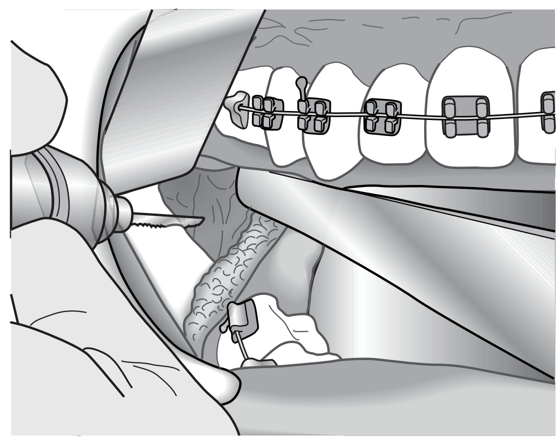

Figure 72.4 Lingual cut being made with a Lindeman bur.

to bone using cutting diathermy (Figures 72.1 and 72.2). Subperiosteal dissection is carried out on the buccal surface of the mandible inferiorly to the antegonial notch. It is not necessary to raise the periosteum over the angle of the mandible. The lingual surface of the ramus of the mandible is then approached by elevating periosteum over the anterior surface of the ramus towards the coronoid process for approximately 2 cm above the occlusal plane. Retraction of mucosa is achieved using either a forked retractor or by clamping the anterior surface of the coronoid process by using a curved Kochers clamp. The lingual surface of the ramus is now exposed by introducing a periosteal elevator above the level of the mandibular foramen and progressing inferiorly (Figure 72.3). Usually, the lingula can be easily identified and the periosteal elevator can be positioned immediately above the lingula and used as a retractor protecting the inferior dental nerve.

The bone cuts

The lingual cut is made using a Lindeman bur as far posteriorly as the lingula and deepened into cancellous bone (Figure 72.4). Care must be taken to ensure that it is sufficiently deep posteriorly. The Kocher and lingual retractor are then removed and a buccal channel retractor inserted.

The buccal bone cut is again carried out using a Lindeman bur and extends from the lower border of the mandible to the lateral mandibular ridge. It extends into cancellous bone. Care must be taken to ensure that the cut extends through the lower border of the mandible as far lingually as possible (Figure 72.5).

The Kocher and lingual retractors are then again inserted, and the joining cut linking the lingual and buccal cuts is performed at the junction between the buccal cortical plate and cancellous bone (Figure 72.6).

The split

A controlled split is carried out. This is commenced using a curved osteotome placed at the junction of the lingual and connecting cuts and tapped through posteriorly so that the superior end of the split line is initiated in a downwards direction from above the lingual (Figure 72.7).

An osteotome is then inserted at the junction of the buccal and connecting cuts and the buccal plate is gradually

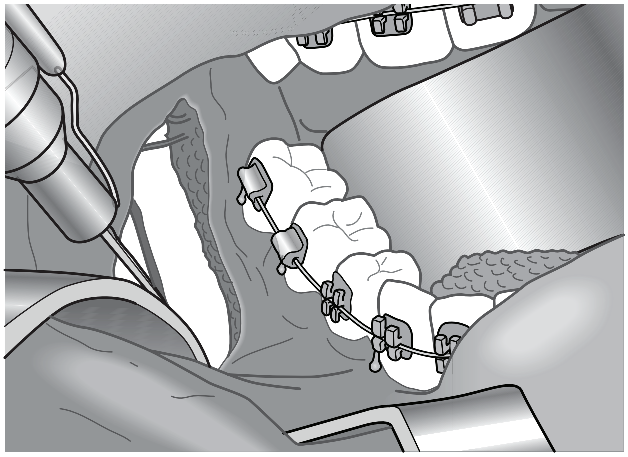

Figure 72.5 Buccal cut being extended down to the lower border of the mandible.

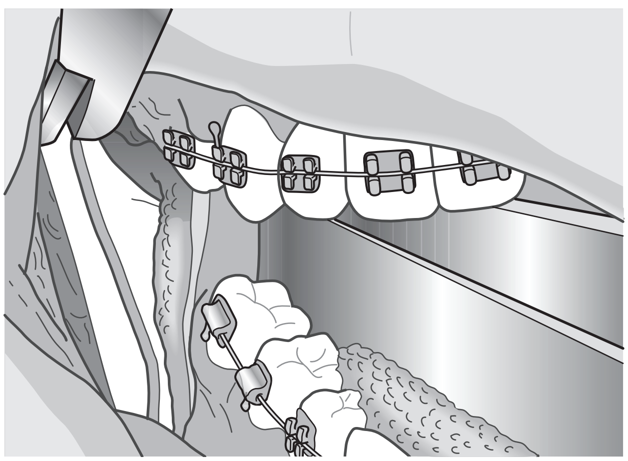

Figure 72.6 The cut joining the lingual and buccal cuts has been completed.

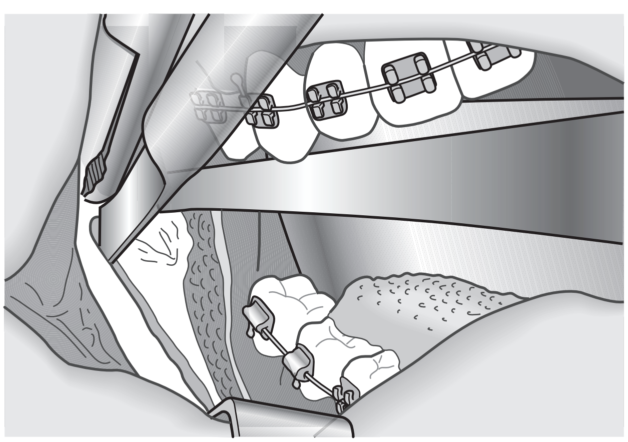

Figure 72.7 The lingual split is being developed using a curved osteotome.

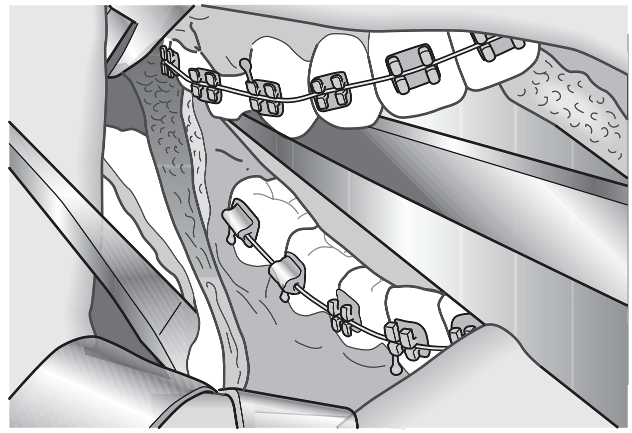

Figure 72.8 The buccal plate is being prized laterally with an osteotome.

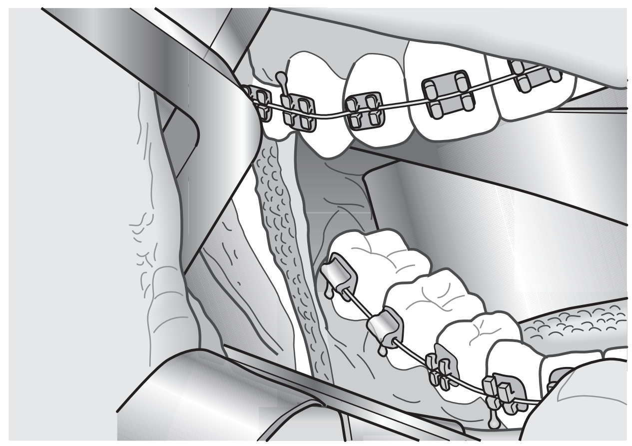

Figure 72.9 The inferior alveolar nerve has been identified and protected.

prised laterally (Figure 72.8). The same osteotome can be used to separate the buccal cortical plate from the cancellous bone. Once the lower border of the mandible can be seen, the osteotomy line can be propagated posteriorly using an osteotome and Smith's spreader to join the lingual cut and complete the split.

The inferior dental nerve is usually easily identified during the split and can be protected (Figure 72.9). However, it can remain completely contained within the distal fragment in which case it is not visualized. If it crosses from the lingual to the buccal side, it may be partly or completely within the bone of the proximal segment. In this circumstance, it must be carefully freed from the surrounding bone using a fine osteotome.

Fixation

After completion of the BSSO, the patient is placed into intermaxillary fixation. Usually, a prefabricated splint is used to locate the correct occlusion.

Fixation of the osteotomy sites can be achieved using either a single buccal miniplate or bicortical screws placed transbuccally (Figure 72.10). Control of the proximal fragment is crucial. The mandibular condyle must be seated in the glenoid fossa and not distracted downwards or forwards. This is largely a matter of feel. The proximal segment is pushed posteriorly and upwards using a curved osteotome (Figure 72.11).

Completion of procedure

The intermaxillary fixation is released, the splint removed and occlusion checked (Figure 72.12). The intraoral incisions are sutured and the cheek incisions are Steri-stripped.

A NOTE ON FIXATION

The osteotomy sites can be fixed with either plates or bicortical screws (Figure 72.13). These can be either titanium or resorbable. In the event of a 'bad split', i.e. lingual (Figure 72.14) or buccal (Figure 72.15) cortical plate fracture, a combination can be used.

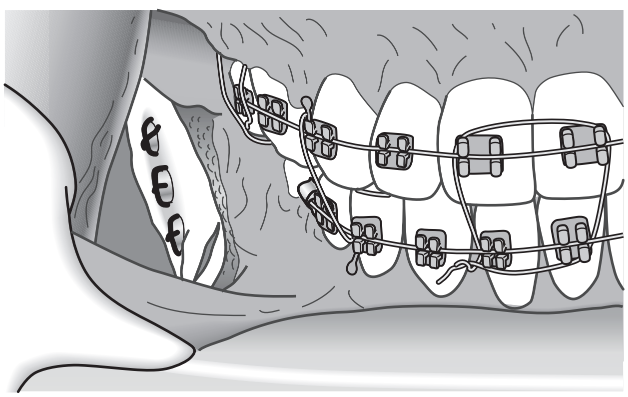

Figure 72.10 The osteotomy has been immobilized with three bicortical screws.

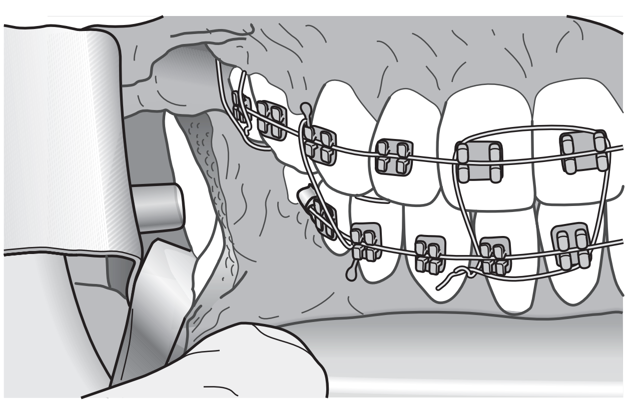

Figure 72.11 Whilst the transbuccal holes are being drilled, the proximal segment is pushed posteriorly with a curved osteotome.

GENIOPLASTY (HORIZONTAL SLIDING OSTEOTOMY)

This was first described in 1958 by Obwegeser.[5] Horizontal osteotomy of the anterior mandible allows

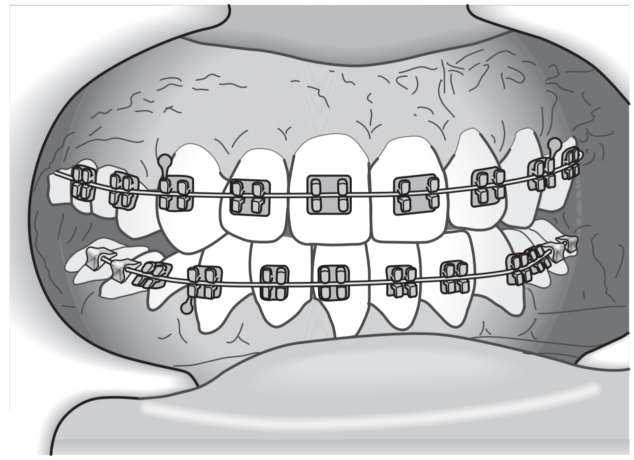

Figure 72.12 The intermaxillary fixation has been released in order to check the occlusion.

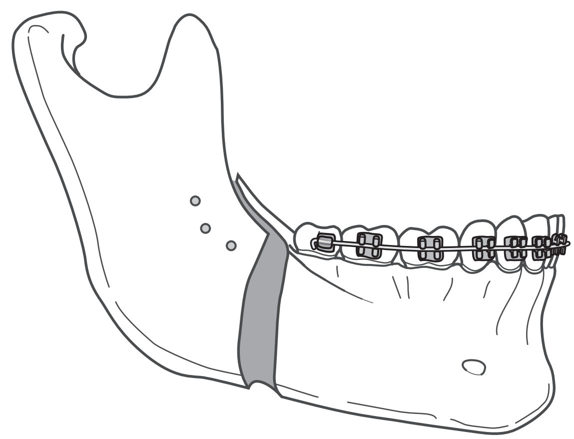

Figure 72.13 The ideal position of the holes when bicortical screws are used for immobilization.

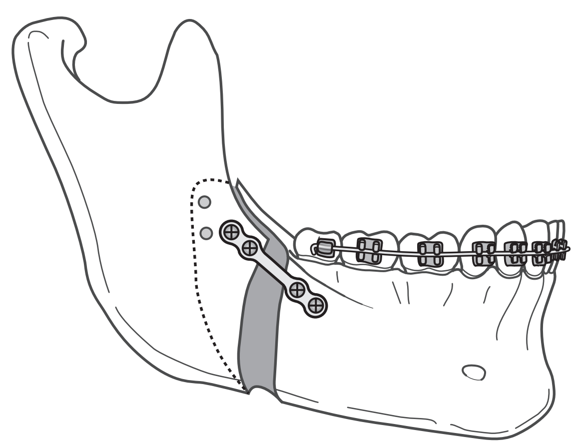

Figure 72.14 An additional bone plate is used when there has been a 'bad' lingual split.

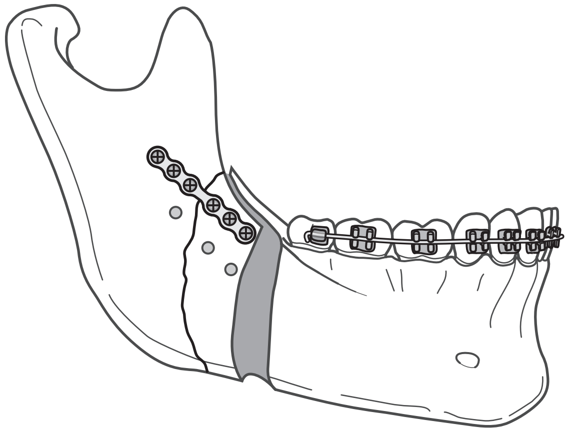

Figure 72.15 In this case, an additional bone plate is being used to control a 'bad' buccal split.

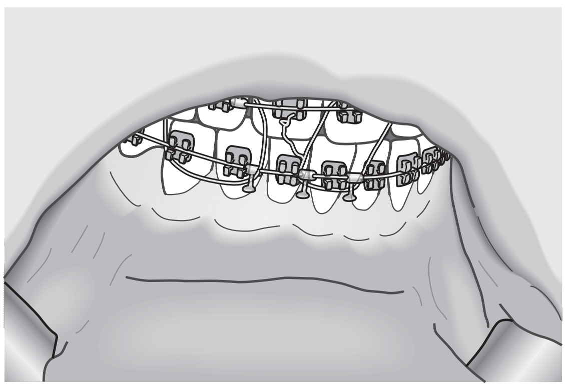

Figure 72.16 A sulcus incision is used to expose the anterior surface of the mandible.

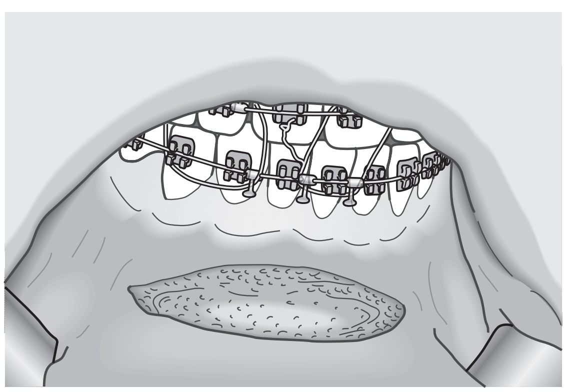

Figure 72.17 The mental nerves are identified laterally.

the chin to be repositioned in three dimensions. It can be advanced or set back to correct retro- or progenia. The lower face height can be either decreased or increased by excising bone or downgrafting the chin. Finally, rotational osteotomy can be performed to correct a lower facial asymmetry.

Surgical technique

If combined with a sagittal split osteotomy, the genioplasty is performed after the BSSO. It is easier if the patient is left in intermaxillary fixation whilst the genioplasty is carried out.

Incision

Using cutting diathermy, an incision is made in the lower lip approximately 5 mm above the reflection of the lower labial sulcus and deepened to the anterior surface of the mandible (Figure 72.16). The mentalis muscles are transected in the process. Subperiosteal dissection is carried out towards the chin prominence. However, it is not necessary to deglove the chin. Extending laterally, the mental nerve is identified (Figure 72.17).

The bone cuts

A reference cut is first made in the line of the mandibular symphysis to mark the midline (Figure 72.18).

An Aufricht retractor is introduced into the lateral extent of the subperiosteal pocket on first one side and then the other below the mental foramen whilst the horizontal osteotomy is performed. The mental nerve is directly visualized and protected. The osteotomy can be completed laterally using an osteotome (Figure 72.19). Having completed the bone cut on the first side, the saw is reversed and the cut extended on the contralateral side to complete the osteotomy (Figure 72.20).

Fixation

The chin is mobilized into the planned position and fixed using either plates or screws. The author uses screws when possible (Figures 72.20 through 72.22). When the chin is advanced, it is held in the planned position using a Kocher clamp. It is often easier to use plates to fix the osteotomy in this situation, particularly when the symphysis thickness is narrow.

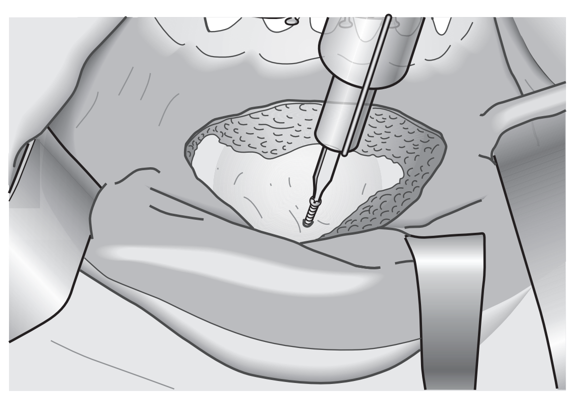

Figure 72.18 A small bone screw is used to mark the midline.

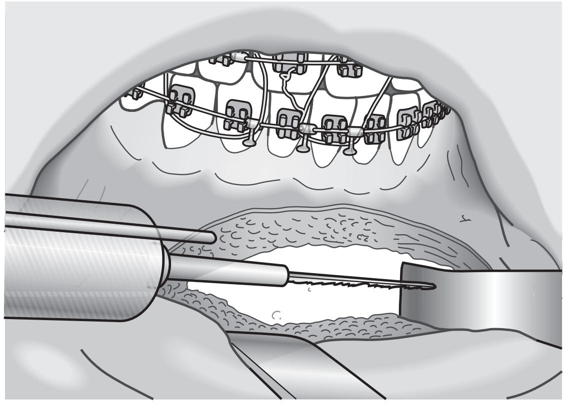

Figure 72.19 The horizontal osteotomy is being done with a reciprocating saw.

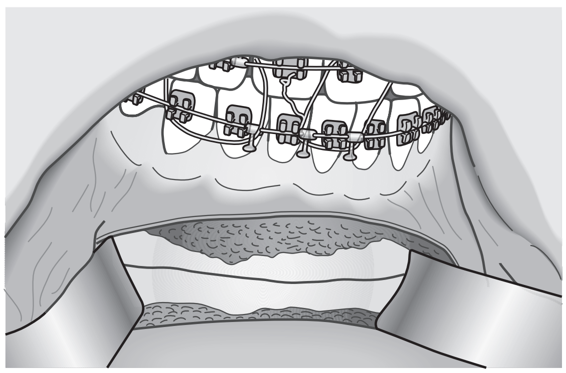

Figure 72.20 The horizontal cut has been completed.

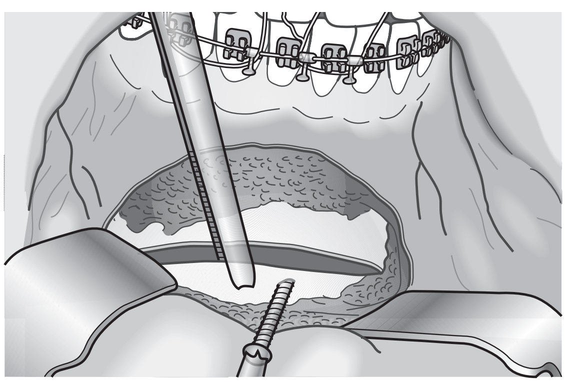

Figure 72.21 The mobilized segment is being held with a Kocher clamp whilst a screw is being inserted to immobilize the osteotomy.

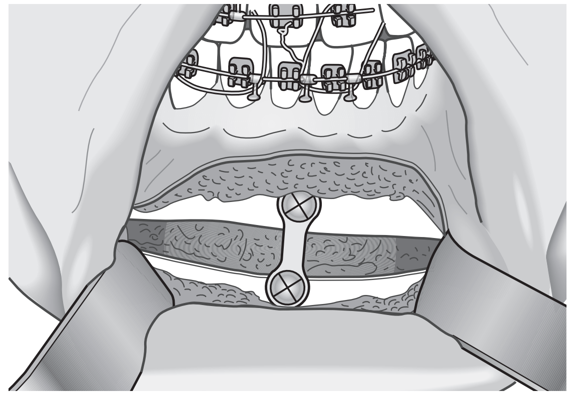

Figure 72.22 A bone plate may be used to immobilize the segment if there is not good bone contact.

Completion

The incision is then closed. The mentalis muscles are repaired. The mucosa is closed using resorbable, continuous sutures. A pressure dressing is applied.

Top tips

- Ensure optimal operating conditions. Use a headlight and ask for hypotensive anaesthesia.
- Keep it simple. Avoid difficult and unusual procedures. The sagittal split osteotomy is uniquely versatile and, once mastered, is easy to perform and predictable. It is easily combined with a genioplasty.
- Perform a controlled split from anterior to posterior.
- Visualize the inferior dental nerve early and protect it.
- Use rigid fixation with either bicortical screws or a plate fixation.

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Orthognathic surgery – maxilla (Le Fort I, II and III)

GEORGE OBEID

CONTENTS

LE FORT I OSTEOTOMY

Indications

- Correction of maxillary
  - Hypoplasia and hyperplasia
  - Vertical excess and deficiency
  - Asymmetry
  - Transverse anomalies
  - Occlusal plane abnormalities
- Obstructive sleep apnoea
- Access to the pharynx and base of skull for resection of tumours

Planning fundamentals

- *Position of the upper incisors in the alveolar bone*
  - One of the cornerstones of planning for a maxillary osteotomy is to understand the position of the upper central incisors as they relate to the upper lip and the face. For this evaluation to be dependable, the central incisors must have the correct location and inclination inside the alveolar process. If at the time of evaluation the incisors are in an abnormal position, appropriate adjustments must be incorporated in the assessment.
- *Vertical position of maxilla*
  - Assess relationship between the upper central incisors to the upper lip. The incisor show is about 2–3 mm in repose; it is normal to show 1–2 mm above the gingivocervical margin when smiling. Since this measurement depends on a normal upper lip length, variation in the length and shape of the upper lip may have significant impact on this measurement. For instance, if the upper lip is abnormally short (males normal values 22 ± 2 mm, females 20 ± 2 mm) the upper incisors should not be moved to accommodate an abnormally short lip. Failure to take that into consideration may lead to imbalance of the facial structures (Figure 73.1).
  - Assess facial thirds which are equal when measured from hairline to glabella, glabella to subnasale and subnasale to soft-tissue menton (Figure 73.2).
- *Anterior–posterior (AP) position of maxilla*
  - Clinical examination
  - Observe the midpoint of the facial surface of the clinical crown of the central incisor as it relates to the forehead in profile, while smiling as described by Andrews. In a well-balanced face, this point does not project beyond glabella. The relationship is universal and is consistent across age, gender and racial groups (Figure 73.3).
  - Cephalometric analysis
  - Sella-nasion-A (SNA) point angle (82°). For this angle to be useful, the inclination of the SN to the Frankfort horizontal should be adjusted to about 7° (Figure 73.4).
  - Maxillary depth angle. NA – Frankfort horizontal (90°) (Figure 73.5).
- *Midline position of the maxilla*: The midline between the maxillary central incisors should relate to the lower central incisors, the philtrum, the chin, the nose and the forehead. Photographs, pencilled in line, a string applied to the face all help determine if an asymmetry is present.
- *Maxillary Cant*: Measure the distance between the medial canthal ligament, to the incisive edge of the central and lateral incisors, and canine on one side and compare it to the other side (Figure 73.6).

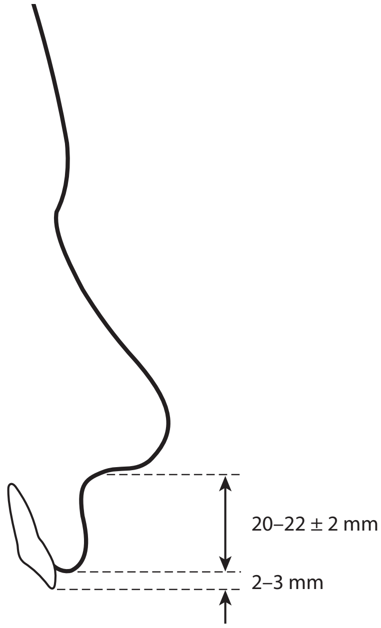

Figure 73.1 Upper lip length and incisor show.

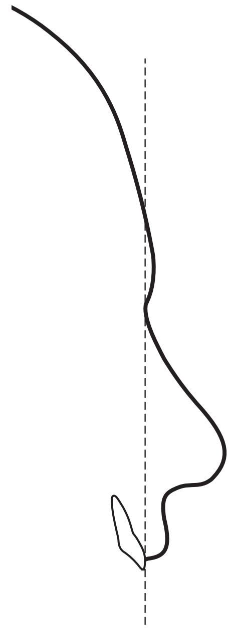

Figure 73.3 Anterior–posterior position of maxilla using relationship of upper central incisor to forehead.

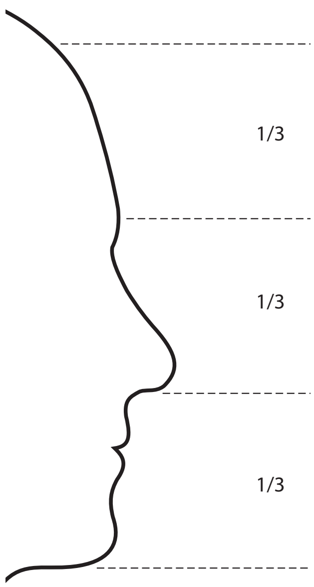

Figure 73.2 Facial thirds.

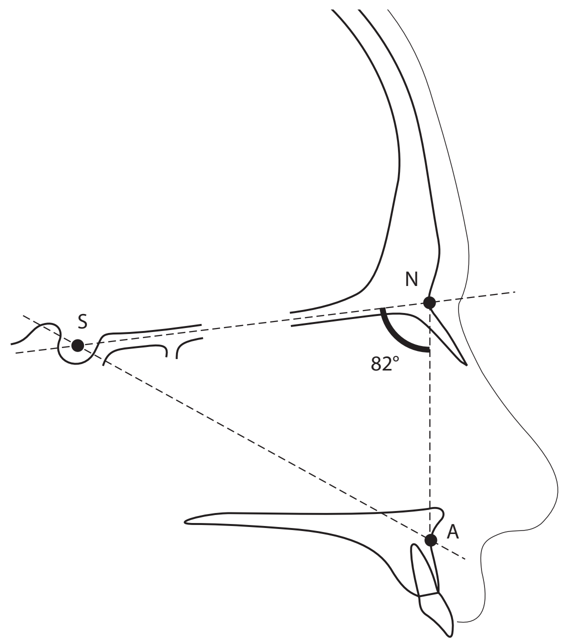

Figure 73.4 Anterior–posterior position of maxilla using Sella-nasion-A angle.

- *Occlusal plane inclination*: The inclination of the occlusal plane has an impact on the aesthetics of the smile, the position of the chin, and the airways. Utilizing the cephalometric measurements, the occlusal plane is typically close to 8° from Frankfort Horizontal (Figure 73.7).

Traditionally, in planning for orthognathic surgery, we depended on clinical examination which may not have always portrayed the true facial deformity of the patient. The ability to obtain three-dimensional (3D) reconstructed data from computerized tomography of the facial skeleton and merge it with the occlusal anatomy of the teeth from dental casts has created a new paradigm shift in the way we plan for orthognathic surgery. This computer-assisted surgical simulation is useful in improving the determination of the midline, the maxillary cant and the inclination of the occlusal plane. It is particularly relevant in recognizing and correcting yaw deformities which would not have been otherwise recognized clinically.

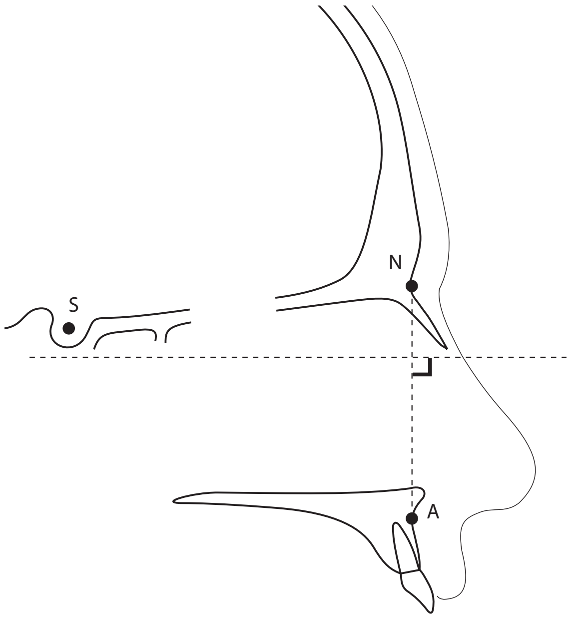

Figure 73.5 Anterior–posterior position of maxilla using facial angle.

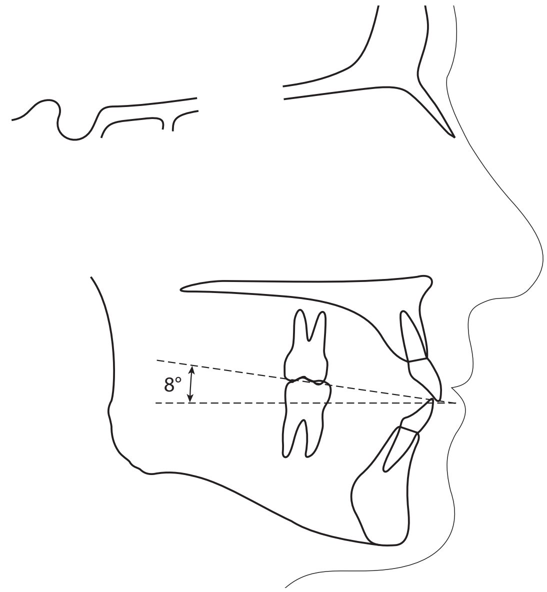

Figure 73.7 Assessment of inclination of occlusal plane.

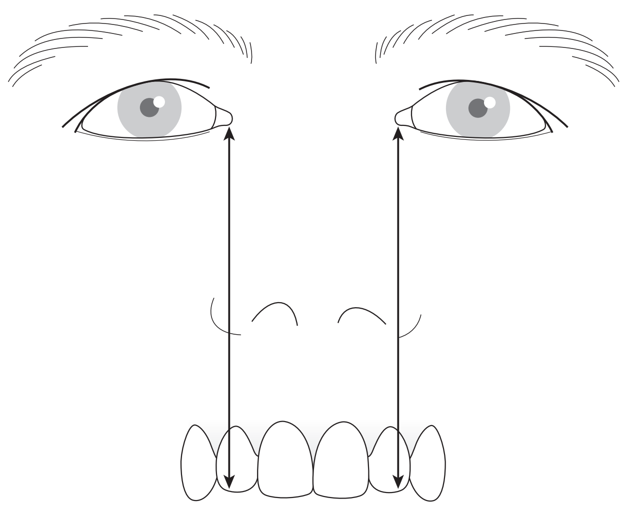

Figure 73.6 Assessment of maxillary cant.

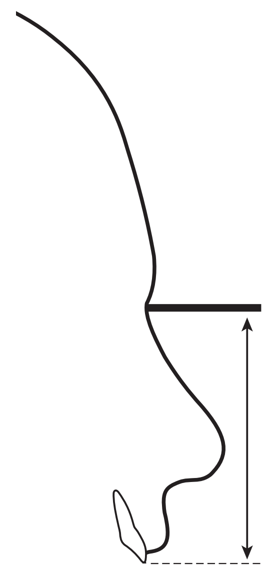

Figure 73.8 External reference marker.

Operation

- Anaesthesia is accomplished with a nasotracheal tube well secured to the forehead.
- About 10 mL of 0.5% Lidocaine with vasoconstrictor is injected in the buccal vestibule for haemostasis.
- Hypotensive anaesthesia, particularly at the time of down-fracture, reduces oozing and improves visibility.
- A non-threaded Kirschner wire is placed in the bridge of the nose to be used as an external reference marker. Distances from the wire to the central incisors are recorded (Figure 73.8).
- Place a circumvestibular incision, using a blade or electrocautery, in the buccal vestibule from molar to molar (Figure 73.9). The use of the electrocautery should be limited; orthodontic forces sometimes bring the apices of the teeth close to the surface outside the bone putting them at risk of thermal injury. Additionally, the use of electrocautery in the anterior region risks the formation of wide scar band and possible shortening of the upper lip.
- Expose the piriform aperture, the infraorbital nerves and the zygomatic buttresses.
- Expose the posterior maxilla by subperiosteal tunnelling to the junction of the maxillary tuberosity with pterygoid plates (Figure 73.8).

- Reflect mucoperiosteum of the floor of the nose, starting with a small Molt curette and then with an angled Freer elevator. Bothersome oozing can be minimized with the use of strips of ribbon gauze impregnated with a vasoconstrictor.
- The lateral bony osteotomy is done in a straight line or in the form of a step. The straight line runs from the pterygomaxillary suture posteriorly to the lateral nasal aperture anteriorly. The osteotomy should be placed below the zygomatic buttress and 4–5 mm above the apices of the maxillary teeth. When a step design is selected the anterior limb of the step is kept horizontal. The step, 4–5 mm in length, is placed in the zygomatic buttress region. The benefit of the step is in reducing the risk of shortening the face as the maxilla is advanced horizontally forwards rather than on a ramp. The osteotomy can be performed with burs or reciprocating saw. Visibility is improved by starting the osteotomy posteriorly and moving forwards (Figure 73.10).
- Score the posterior wall of the maxillary antrum, without going through it, with a thin spatula osteotome introduced through the lateral osteotomy and directed in a downwards direction.
- Separate the nasal septum with the double beaded osteotome directed downwards and backwards (Figure 73.11).
- Separate the maxilla from the pterygoid plates with a small curved osteotome placed at, or just behind, the tuberosity, as perpendicular as possible, and driven in a downward and medial direction. The operator's index finger is placed inside the mouth on the palatal side of the tuberosity to verify the position and direction of the osteotome (Figure 73.12).

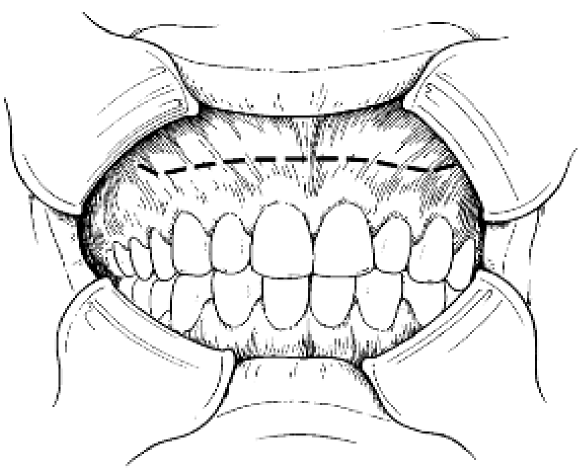

Figure 73.9 Soft tissue incision in buccal vestibule about 1 cm above the junction of mobile and fixed mucosa. The incision is curved slightly cranially in the posterior region.

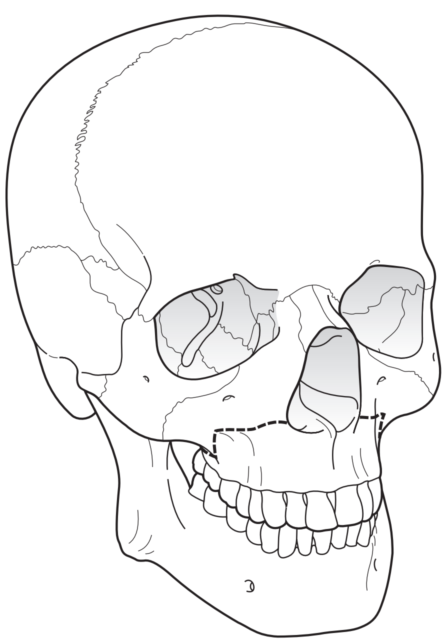

Figure 73.10 Outline of Le Fort 1 osteotomy.

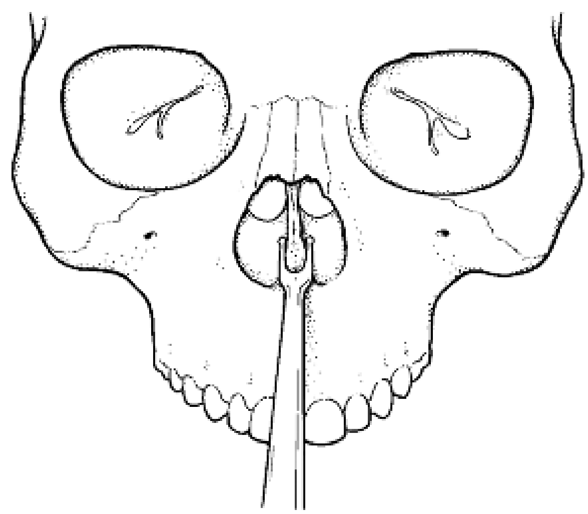

Figure 73.11 Septal osteotome is used to separate the nasal septum from the maxilla. Note the blunt end of this instrument which avoids tearing the nasal mucosa.

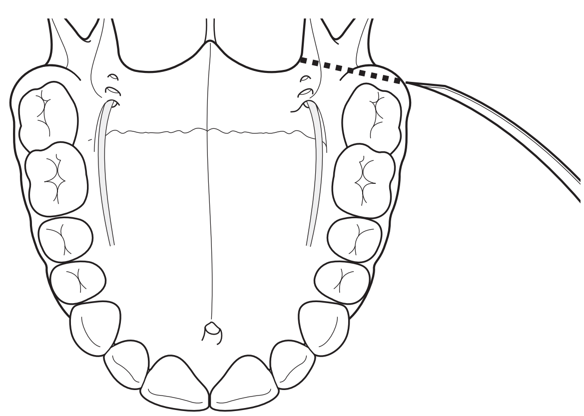

Figure 73.12 Place a slightly curved osteotome to cut through the tuberosity in a downward and medial direction.

- While protecting the nasal mucosa with a periosteal elevator, cut the lateral nasal wall with a thin spatula osteotome placed anteriorly in the nasal aperture and directed in a posterior and downward direction to about 30 mm without reaching the descending palatine vessels. This step is repeated with increasingly thicker osteotomes, slowly wedging the maxilla down (Figure 73.13).
- Down-fracture the maxilla with light digital pressure, if resistance is encountered, repeat use of the osteotome. Down-fractured maxillas that have pterygoid plates attached to the tuberosity have markedly restricted movements. The descending palatine vessels can be safely coagulated. If indicated, impacted maxillary third molars can be removed at this stage. With the maxilla in the down-fractured position, the third molar can be elevated after removing the thin buccal bony cover with an osteotome or a Coupland chisel. Erupted third molars should be removed prior to the down-fracture of the maxilla or preferably 4 weeks prior to surgery (Figure 73.14).
- Mobilize the maxilla with spreaders, Seldon elevators, curved osteotomes and Tessier mobilizers in addition to digital manipulation. The use of Rowe's disimpaction forceps may damage the palatal mucosa and its use should be limited. Once the desired mobility is accomplished, the maxillary and mandibular teeth are wired together with or without a wafer splint. With the maxilla and mandible attached together and the condyles properly seated in the glenoid fossas, the complex is passively closed to the desired vertical dimension using the external reference point (Figure 73.15).
- Reduce the nasal septum enough to prevent buckling. Deep bony structures are trimmed to allow free movements without interferences. To avoid excessive bone trimming, the lateral wall of the maxilla is reduced under direct vision, trimming only the bony spots that are preventing the planned movement.
- When posterior maxillary expansion is needed, paramedian osteotomies on the nasal side of the hard palate are done while the maxilla is in the down-fractured position. The osteotomies are placed about 6–7 mm from either side of the midline and extend forwards to meet just behind the opening of the incisive canal. From this point, the bony osteotomy is extended forwards in the midline of the maxilla and advanced between the roots of upper central incisors. The papilla between the incisors is kept mostly undisturbed but the soft tissues above it are gently freed from the bone to finish the osteotomy cut between the teeth. Once all the cuts are done, the segments are gently mobilized by an osteotome and slowly stretched to reach the desired movement. The osteotomy can be accomplished with a fine bur, a slim saw, or a piezoelectric cutting instrument. It is very important to avoid the perforation of

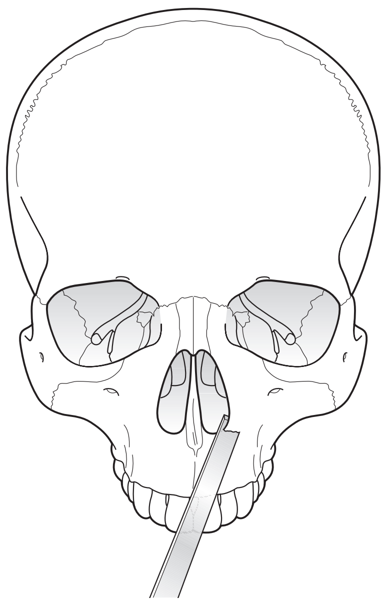

Figure 73.13 The lateral nasal wall is cut with an ostotome with a blunt end so as not to damage the nasal mucosa.

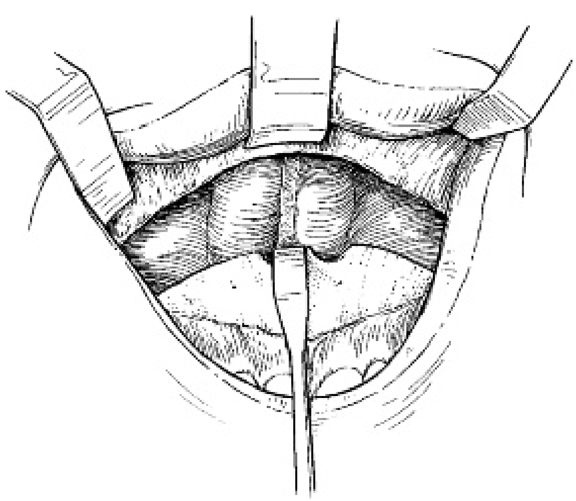

Figure 73.14 Down-fractured maxilla.

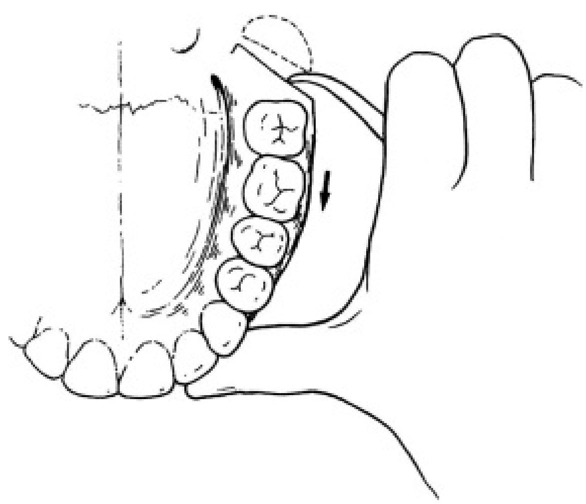

Figure 73.15 Curved instruments such as the Seldon elevator are used to mobilize the maxilla and move it forward.

the palatal mucosa and the damage to the buccal papilla (Figure 73.16).

- When the maxilla needs to be separated into three pieces, similar cuts are performed in the back of the hard palate and then, in addition to connecting to osteotomies across the midline of the hard palate, the cuts are extended laterally to finish, most often, between the upper canines and the lateral incisors on each side. To avoid damage to the teeth adjacent to the planned osteotomies, it is necessary to have the roots orthodontically diverged prior to surgery. It is not necessary to have a diastema between the crowns.
- Patients undergoing maxillary impaction may require the removal of bone from the floor of the nose equivalent to the desired impaction of the maxilla. Additionally, patients undergoing maxillary impaction may require the removal of the inferior turbinates to provide needed space and to reduce nasal airway obstruction. With the maxilla in the down-fracture position, the nasal mucosa is incised lengthwise on both sides and the inferior turbinates are resected with scissors and electrocautery. The nasal mucosa is then closed with 4–0 chromic gut sutures.
- Fixation of the maxilla is ideally done with two plates and screws on each side – one in the piriform rim area and a second one in the malar buttress region. The maxilla, still attached to the mandible, is brought passively and without any interferences to its final position using the mandibular condyle as a guide. It is critical to have the condyle properly seated in the glenoid fossa. This step begins prior to surgery, by understanding the patient's specific occlusion and centric relation. If interim splints are used they must be accurate, otherwise a cant or side to side movements of the maxilla may occur. The anterior plates are placed first; constantly referring to the external reference point to avoid inadvertent shortening or lengthening the midface. Plate placement requires precision; any inaccuracies lead to malocclusion (Figure 73.17).
- Verify accuracy of the fixation. This can be done by manually maintaining the mandible in occlusion while the IMF wires are removed. Observing any shift of occlusion while the teeth are slowly released is helpful in recognizing an error in fixation. Malocclusion that is secondary to inaccurate plating needs to be addressed at this stage.
- Alar cinch suture is often needed to prevent alar flare that occurs as the result of the maxillary surgery. Evert the lip and grasp the fibrous tissue located immediately below the alar cartilage. Pass a 0 Vicryl or similar suture through the tissue and visualize the pulling effect on the alar region to assure proper placement of the suture. Repeat this step on the opposite side. The suture is tied to the desired tension in the midline (Figure 73.18).

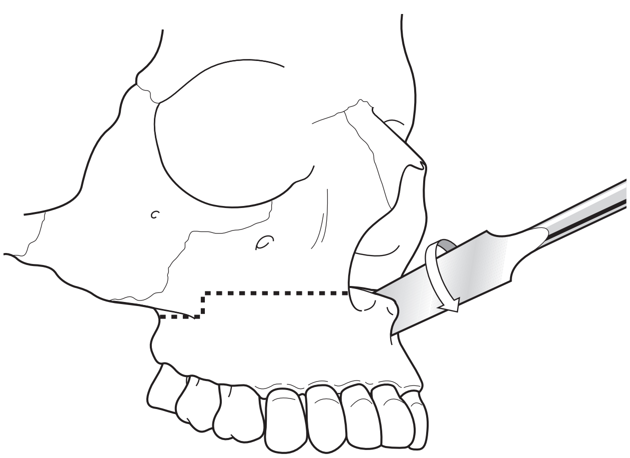

Figure 73.16 For small maxillary expansion, osteotomes are used for opening the midline sutures to expand the maxilla posteriorly.

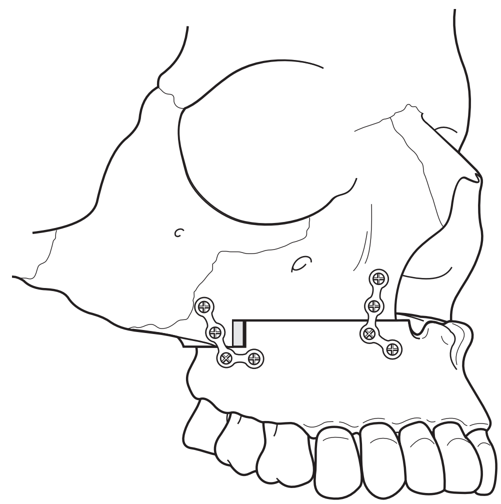

Figure 73.17 Two small plates, in the piriform rim and zygomatic buttress, are used to fix the maxilla.

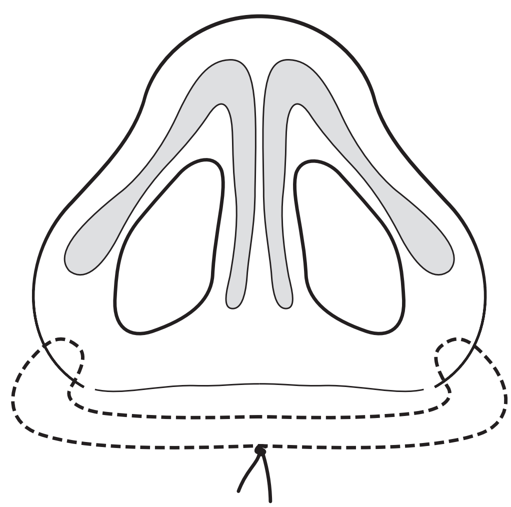

Figure 73.18 Alar cinch suture.

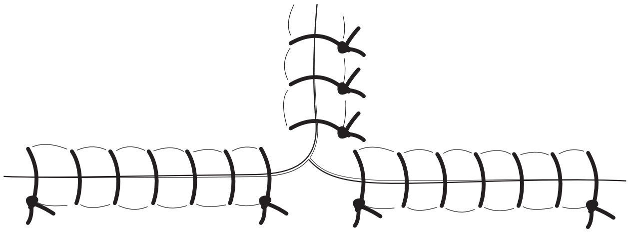

Figure 73.19 V-Y closure of soft-tissue incision.

- V-Y closure of the anterior wound can affect the protrusion of the upper lip and preserve its length. The rest of the maxillary incision is closed in one layer, which should include mucosa and muscle, with running 3–0 Vicryl suture (Figure 73.19).
- Light elastics may be applied between the maxillary and mandibular teeth.

Post-operative care

- Obtain cephalometric radiographs to verify the planned movement and to monitor any future relapse.
- Check the occlusion; minor occlusal interdigitation problems are corrected with light elastics. More significant midline or AP discrepancies may require a return to the operating room for correction.
- Monitor for infection and wound dehiscence.
- Orthodontic tooth movement can be started as early as 4–6 weeks post-surgery.

OSTEOTOMIES ABOVE THE LE FORT I LEVEL

High Le Fort I osteotomy

Principles

Also known as quadrangular Le Fort I. It is similar to the standard Le Fort I except that it extends higher on the anterior wall of the maxilla and the body of the zygoma.

Indication

Maxillary and zygomatic horizontal deficiencies in patients that have normal nasal projection. The principal movement is advancement with midline split when necessary.

Operation

- Identical to Le Fort I approach except for the osteotomy on the lateral wall of the maxilla (Figure 73.20).
- Start bony cuts low at the lateral wall of the nose.
- Extend superiorly to just below the infraorbital rim.
- Continue laterally, below the infraorbital rim, skirting around the infraorbital foramen, to the zygomatic body.
- Turn downwards into the zygomatic buttress.

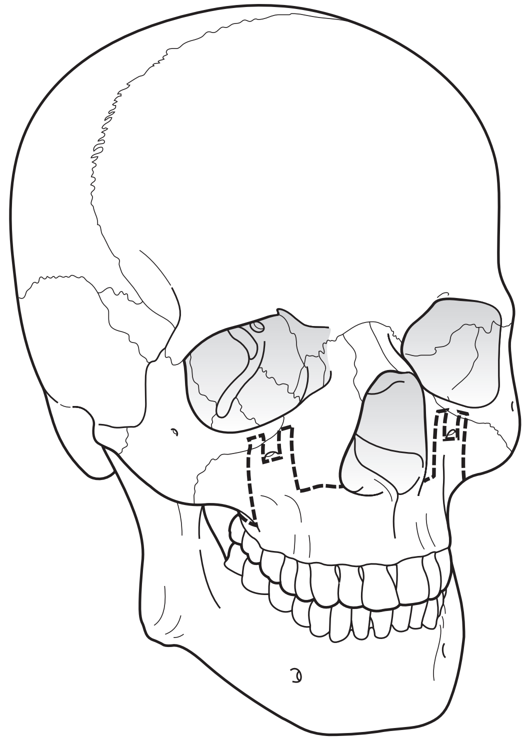

Figure 73.20 Outline of high Le Fort I osteotomy.

- Continue horizontally backwards to the pterygomaxillary fissure.
- Down-fracture the maxilla with attention not to break the thin lateral maxillary wall.
- Fixation with miniplates and screws and bone graft as needed.

Le Fort II osteotomy

Indication

Adult patients with nasomaxillary hypoplasia to accomplish mostly advancement and some downward movements.

Operation

- Intraoral circumvestibular incision from molar to molar
- Bilateral oblique paranasal skin incisions or coronal flap
- Bony outline
    - Horizontal line across the nasofrontal and nasomaxillary sutures.
    - Extend vertically downwards through the lacrimal bone, keeping the canthal ligaments intact.
    - Continue posterior to the lacrimal apparatus to cross the medial aspect of the infraorbital rim.
    - Continue from the intraoral side, in a downward and lateral direction to finish in the pterygomaxillary fissure (Figure 73.21).
    - Separate the nasal septum from the base of the skull with an osteotome starting at the level of the bridge

of nose and sloping in a posterior and inferior direction. Pre-operative computed tomography (CT) scan can help assess the midline structures and their proximity to the proposed septal osteotomy (Figure 73.22).
    - Mobilize with Rowe's disimpaction forceps and Tessier mobilizers.
- Fixation is with miniplates and screws with bone grafts placed primarily in the bridge of the nose and other areas as needed.

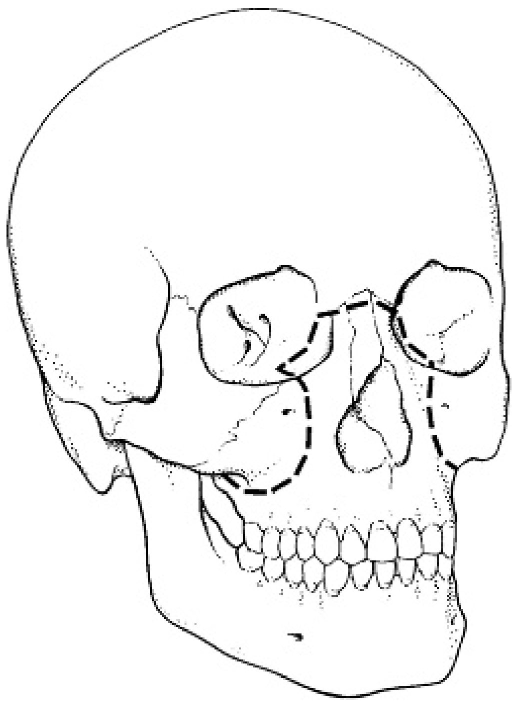

Figure 73.21 Outline of the Le Fort II ostetotomy.

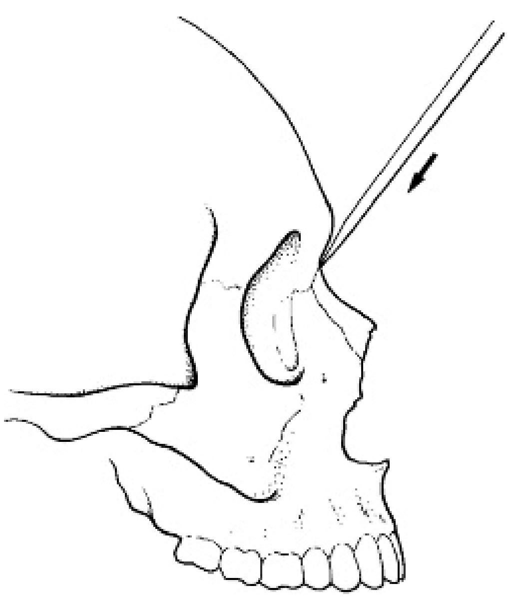

Figure 73.22 Direction of nasal septum cut the level of the nasal root.

Quadrangular Le Fort II osteotomy

Principles

Follows similar outline to the high Le Fort I osteotomy with the exception of including the infraorbital rims. The infraorbital nerve is overly manipulated in this osteotomy increasing the risk of long-term injury (Figure 73.23).

Indication

Maxillary and zygomatic deficiencies in patients that have scleral show and normal nasal projection. The movements are mostly advancement. Often, aesthetic and functional movements needed at the tooth level differ from what is needed at the infraorbital rim level.

Operation

- The entire osteotomy can be accomplished from an intraoral circumvestibular incision; the orbital floor is cut with osteotomes introduced from either side of the osteotomized infraorbital rims. If unfeasible, additional skin or transconjunctival access is performed.
- Fixation is with miniplates and bone graft as needed.

Le Fort III osteotomies, transcranial frontofacial osteotomies, monobloc or sagittal bipartition

Indication

Correction of concurrent nasal, orbital, zygomatic and maxillary deficiencies in mostly syndromic or

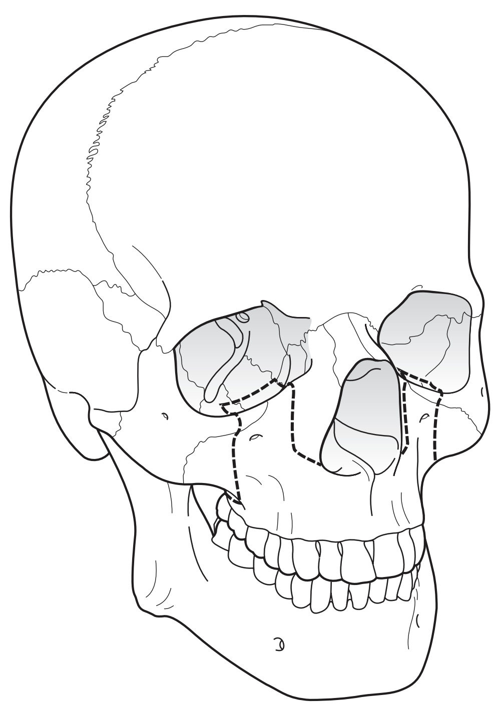

Figure 73.23 Outline of the quadrangular Le Fort II osteotomy.

post-traumatic patients. Abnormalities in the shape of the forehead will affect the selection between a transcranial approach and a subcranial Le Fort III osteotomy.

Timing of surgery is selected on a case-by-case basis with early intervention often influenced by severe proptosis, sleep apnoea, and need to improve the child's appearance around school age. It is important to take into account that early intervention will result in restrictive growth on the facial skeleton, and even with overcorrection, repeat surgery, once the growth is completed, may be indicated.

Operation

- Tracheostomy may be indicated.
- Coronal flaps; additional access to the orbital floor may require lower cutaneous eyelid incision or a transconjunctival approach.
- Thee bilateral bone cuts for the Le Fort III osteotomy involve the following:
  - The zygomatic arch, frontozygomatic suture and lateral orbital wall.
  - Extends to the floor of the orbit and the infraorbital fissure.
  - Continues behind the nasolachrymal apparatus onto the medial wall of the orbit to the bridge of the nose.
  - The nasal septum is separated from the base of skull as described for Le Fort II osteotomy.
  - The pterygoid plates are separated from the tuberosity with an osteotome introduced either from the coronal flap approach or through a small intraoral incision in the tuberosity region.
  - Concurrent midfacial and supraorbital rim deficiencies require a transcranial approach whereby the supraorbital rims and the midface are advanced as a single unit 'monobloc'. The outline for this osteotomy differs from that of the Le Fort III procedure in that the superior cuts run across the anterior cranial fossa to include the entire orbital rim.
  - Patients with associated hypertelorism and palatal constriction can, in addition, have 'facial bipartition'. The face is divided in the central area down to the hard palate and a predetermined column of bone is removed. As the two halves are brought together, the hypertelorism, as well as the palatal constriction are corrected and the face is advanced as single unit.
  - Mobilize with spreaders, Rowe's disimpaction forceps and Tessier mobilizers, avoiding unplanned fractures which are common in the infraorbital rim and the palate.
  - Preserve medial canthal attachment whenever possible. Should there be need to detach it, appropriate canthopexy is done at the conclusion of surgery.
  - Mobilize the face to the planed position and temporarily wire together the maxillary and mandibular teeth.
  - Blocks of autogenous bone graft, calvarial, rib or iliac crest, are placed primarily in the areas of the zygomatic arch, lateral orbit wall and nasal bridge.
  - Use miniplates and screws to stabilize the osteotomy and the grafted bone. Concerns of migration of metal plates and restriction of growth make a strong case for the use of biodegradable plates and screws in children.
  - Decision to release of the intermaxillary fixation depends on the stability of the osteotomy.
  - Dental arch discrepancies may require an additional Le Fort I osteotomy. Although this procedure can be done concurrently with the midface advancement, it is preferable to do it separately at a later date.

Top tips

- Meticulous planning entails placing the upper central incisors in an ideal vertical and AP position, in addition to having the occlusal plane levelled in the proper inclination.
- External reference point is essential in placing the maxilla in the desired position.
- Proper seating of the condyles in the fossa while fixing the maxilla.
- Eliminate any bony or septal cartilage interferences.
- Plate bending should be accurate; minor imperfections lead to malocclusion.

SUGGESTED READINGS

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74

Mandibular distraction osteogenesis by intraoral and extraoral techniques

DAVID A WALKER

CONTENTS

INTRODUCTION

Distraction osteogenesis (DO) is a powerful technique utilized to gradually lengthen the mandible significant distances. DO creates new bone without the need for bone grafting and donor site morbidly. The distraction technique requires proper understanding and application of the biologic principles of DO that are age appropriate and anatomically sound. DO has a wide range of applications (Table 74.1) and requires selection of an appropriate intraoral or extraoral distraction device.

Table 74.1 Indications for mandibular distraction osteogenesis

1. Severe mandibular retrognathia/micrognathia
2. Craniofacial syndromes: Hemifacial micosomia, Treacher Collins syndrome, Nager syndrome, Pierre Robin sequence
3. Post-traumatic deficient mandibular growth and temporomandibular joint ankylosis
4. Severe mandibular asymmetry
5. Revision mandibular orthognathic surgery
6. Mandibular retrognathia with obstructive sleep apnoea
7. Mandibular retrognathia with temporomandibular joint disease or juvenile rheumatoid arthritis
8. Mandibular defects from tumour resection

PRE-OPERATIVE ASSESSMENT

A thorough history and clinical examination is appropriate with utilization of diagnostic imaging; including panoramic, posterior–anterior and lateral cephalometric radiographs. Computed tomography (CT) scans with three-dimensional (3D) reconstructions of the mandible and temporomandibular joint are helpful. Dental study models mounted on a semi-adjustable articulator with prediction model surgery are of benefit. In selected instances, stereo lithographic models may aid in treatment planning. Standardized 3D cephalometric prediction tracings are appropriate. All clinical and diagnostic tools are utilized to plan out the proper 3D distraction vector selection.

DO device selection is based on available bone stock, ease of application, distance of DO and ability to adjust the distraction vector post device placement. It is the author's preference to utilize an intraoral device (Tables 74.2 and 74.3) although extraoral devices, in selected instances, have advantages (Tables 74.4 and 74.5).

ANAESTHESIA CONSIDERATIONS

Standard pre-operative medical evaluation, diagnostic tests and anaesthesia consultation regarding the patient's airway are appropriate. Many of the patients undergoing mandibular lengthening by DO have severe mandibular retrognathia with significantly compromised airways. Pre-operative polysomnography is a strong consideration in patients with suspected obstructive sleep apnoea. An awake fibre-optic nasoendotracheal intubation of the trachea may frequently be required. Distraction procedures for lengthening of the mandible are more commonly carried out under general anaesthesia although in selected cases sedation and local anaesthesia has been used.

Table 74.2 Advantages of intraoral distraction osteogenesis

1. Allows bidirectional and tridirectional mandibular lengthening of 10–30 mm and avoids intermaxillary fixation
2. Avoids external skin scars of distraction, pin loosening or pin tract infection
3. Allows longer consolidation times with minimal to no skeletal relapse after extreme mandibular lengthening
4. Can be applied to neonates, infants, paediatric and adult patients
5. Avoids more invasive bone grafting procedures and potential donor site morbidity
6. Can be utilized for mandibular widening
7. Potential for less temporomandibular joint adverse effects in response to asymmetric lengthening
8. Decreased length of hospital stay and cost compared with bone grafting with less chance of blood transfusion

Table 74.3 Disadvantages of intraoral distraction osteogenesis

1. Requires additional pre-operative work up and is technique sensitive
2. Requires patient compliance, increased post-operative care and monitoring
3. Requires second procedure for DO device removal

Table 74.4 Advantages of extraoral distraction devices

1. Applicable to small mandibles in infants and small children due to less available bone stock
2. Extraoral device results in less disruption to periosteum and blood supply
3. Able to distract greater distances than intraoral devices
4. Offers the potential for three-dimensional vector adjustments after device placement. Adjustments can be made in the horizontal vertical and transverse planes

Table 74.5 Disadvantages of extraoral distraction devices

1. External skin scars
2. Distraction pin loosening
3. Pin tract infections
4. Psychosocial considerations
5. Inadequate consolidation time resulting in skeletal relapse
6. Temporary or permanent cranial nerve VII palsy

OPERATIVE TECHNIQUE FOR INTRAORAL DISTRACTION DEVICE PLACEMENT

The patient is placed in a supine position with appropriate head support and is prepped and draped in the normal fashion for an oral and maxillofacial surgical procedure. The author prefers appropriate intravenous antibiotic prophylaxis. After establishing general anaesthesia, preferably by nasoendotracheal methods, local anaesthesia (typically 2% lidocaine with 1/1,00,000 epinephrine or 0.5% bupivacaine with 1/2,00,000 epinephrine) is infiltrated throughout the planned area of incisions. Care is taken to avoid toxic local anaesthetic dosages, particularly in infants and children. A bite block is placed on the contralateral side to open the mandible and bring the ramus forwards. An incision is made over the external oblique ridge a distance of 2–3 cm. The length of incision is based on the length of osteotomy and degree of surgical access. A sharp dissection is carried out through buccinator muscle down to the external oblique ridge. The subperiosteal dissection is carried out exposing the anterior aspect of the ramus of the mandible to the level of the insertion of the temporalis muscle and a notched ramus retractor is used to retract tissues. The subperiosteal dissection is carried out down to the angle of the mandible and the antegonial notch region, stripping off the masseter muscle. The dissection is carried out anteriorly to an extent that is required for placement of the distraction device. Care is taken to identify the mental nerve, particularly in infants and children. A careful superior medial subperiosteal dissection is carried out at the body ramus junction in preparation for the osteotomy cut and to protect the lingual nerve.

The planned osteotomy is a linear osteotomy at the body ramus junction, distal to the second molar and is placed in an oblique angle (it is helpful to remove the third molar if present some 3–6 months predistraction). The superior and inferior aspect of the osteotomy is located and marked with a 701 burr. The lateral cortex osteotomy is completed with the 701 burr or reciprocating saw. Appropriate pre-operative diagnostic imaging will help to identify the position of the inferior alveolar neurovascular bundle. The inferior border osteotomy is made in a through-and-through fashion to the medial aspect of the mandible with a channel retractor in place to avoid the facial artery and vein. Care is taken to ensure that this cut does not encroach upon the inferior

alveolar neurovascular bundle. The superior aspect of the osteotomy cut is not completed at this time.

Prior to placing the sterile distraction device (Figure 74.1), it is important to open and close the device to ensure all components are functional and then the device is typically placed at the zero position. The intraoral distraction device is contoured with plate bending pliers to lie passively on the lateral aspect of the mandible. It is particularly important to ensure the correct distraction vector in three planes of space, which is more frequently parallel to the occlusal and sagittal planes rather than parallel to the inferior border of the mandible (Figure 74.2a–e). It is helpful during this stage of the operation to have the mouth closed by a surgical assistant. Screw holes are drilled, one anteriorly and one posteriorly, and screws (preferably 2.0 mm) are utilized to secure the device. If access is difficult posteriorly, a 5 mm percutaneous stab incision can be utilized for introduction of a trocar through which drilling and screw placement can occur. It is advisable to place three to four screws per bony segment a minimum of 5 mm away from the edge of the osteotomy. The length of screws is dependent on the position of important structures such as the inferior alveolar neurovascular bundle, teeth roots and developing tooth buds in infants and children. The DO device is typically secured with a combination of monocortical and bicortical screws.

After the distraction device is secured, and with adequate soft-tissue retraction with a seldin retractor on the medial aspect of the mandible, the superior aspect of the body ramus osteotomy is now completed utilizing a 701 burr and reciprocating saw leaving a small area of bone around the lingual aspect of the inferior neurovascular bundle. Initially, a wedging osteotome is tapped into place superiorly above the inferior alveolar nerve, and utilizing a torquing motion a fracture is created through the remaining portion of the mandible. At this stage, it is important to open the distraction device and see that the bony segments move freely and also to inspect the inferior alveolar neurovascular bundle. If there is difficulty in separating the bony segments, the distraction device may be removed, the osteotomy completed and device reapplied.

Placement of the distraction activation arms is undertaken prior to closure. The activation arm can emerge

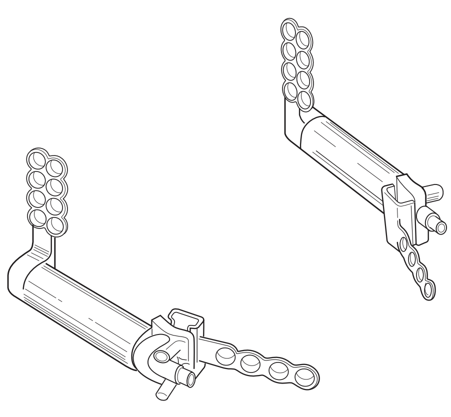


Figure 74.1 Left and right bidirectional telescopic mandibular distractor (Innova Life Sciences Corporation, Toronto, Canada).

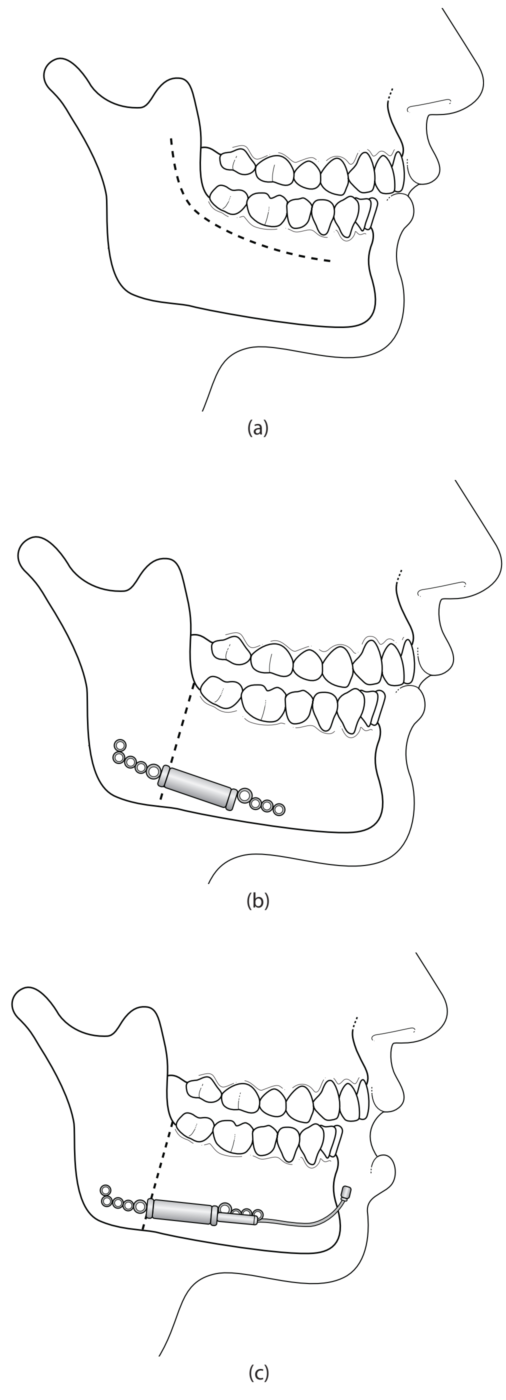
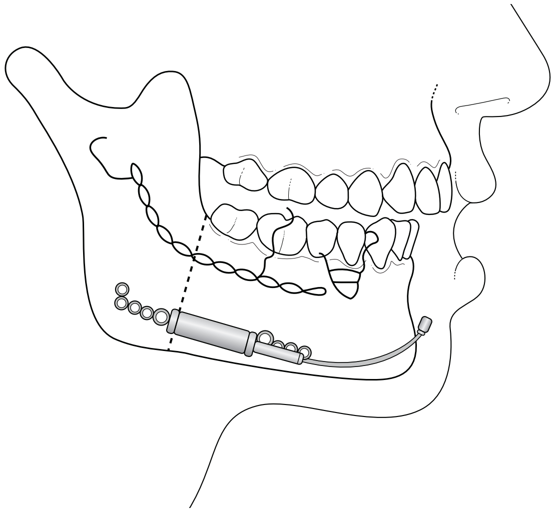
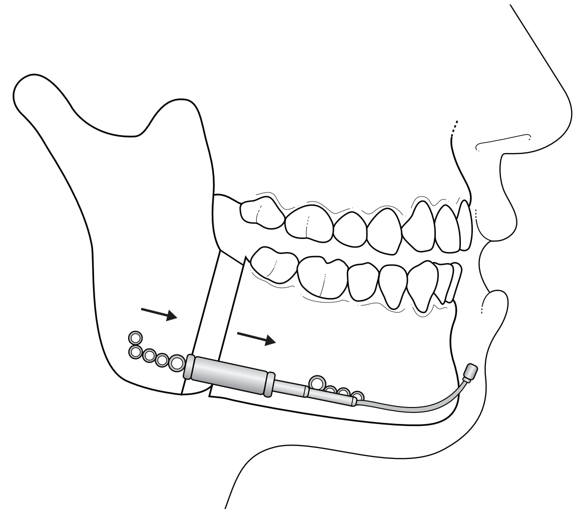


Figure 74.2 (a) An incision is made through mucosa down through buccinator muscle over the external oblique ridge. The distance is 2–3 cm based on planned surgical access and distraction device size. (b) The bidirectional telescopic mandibular distractor is contoured and secured on the lateral aspect of the mandible after partial completion of the osteotomy at the body ramus junction. (c) The bidirectional telescopic mandibular distractor distracter has been secured with monocortical and bicortical screws and the osteotomy is completed. (*Continued*)



(d)



(e)

Figure 74.2 (*Continued*) (d) The activation arm can be placed such as it emerges transmucosally or percutaneously depending on the size of the mandible and surgical access. (e) The distraction device is activated to ensure complete movement of both segments of the mandible and the inspection of the inferior alveolar neurovascular vascular bundle.

transmucosally or percutaneously depending on the size of the mandible or surgical access. If it is elected to have the activation arm exit percutaneously, a small incision is made in the symphysis region of the mandible approximately to the level of the inferior border. It is important that there is no soft-tissue drag on the exiting area of the activation arm. Copious irrigation is carried out and after haemostasis is achieved, the mucosa is closed with a combination of horizontal mattress sutures with 3/0 or 4/0 Vicryl, and a running 4/0 chromic gut for water-tight closure. Most cases require bilateral application of distraction devices. Occasionally, unilateral distraction may be undertaken in younger patients.

OPERATIVE TECHNIQUE FOR EXTRAORAL DISTRACTION DEVICE PLACEMENT

The external distraction device can be placed through an external percutaneous submandibular approach or by a combination of intraoral and extraoral approaches.

Combined intraoral and extraoral approach

An intraoral approach as described previously is undertaken and the osteotomy is partially completed. Percutaneous incisions (1–1.5 cm) are placed in the submandibular area close to the planned area of pin placement. The pins are best placed approximately 6–8 mm away from the distraction osteotomy site and should be 4 mm apart depending on the distraction device (Figure 74.3a–d). Pinhole sites will determine the initial vector of distraction and should be placed in locations based on pre-operative diagnostic studies. In a four-pin device, the skin or soft tissue is pinched between the two pairs of pins to reduce the length of resulting scar. Fifty millimetre half pins are inserted through a trocar through the external incisions. The external distraction device is attached to the pins. The completion of the osteotomy is then accomplished in the superior border as described previously. The devices are opened to allow direct visualization of the distraction osteotomy site and then backed down to zero position.

Extraoral approach

The osteotomy and device placement can also be undertaken through a totally extraoral approach to the mandible, in which case a bolster underneath the shoulders and neck with the head extended somewhat improves access to the submandibular region. The classic Risdon or submandibular approach is utilized with the skin incision being slightly higher, close to the inferior border. The skin and subcutaneous tissues are incised, the platysma muscle is divided with care being taken to ensure identification and preservation of the marginal mandibular branch of the facial nerve. A blunt dissection is carried out down the inferior border of the mandible and angle region. In order to provide adequate surgical access, the facial artery and vein frequently require dissection, clamping, transection and ligation. A subperiosteal dissection is carried out stripping off the masseter muscle and anteriorly to visualize areas of pin placement. Depending on the position of the incision the distraction pins can emerge through the incision or in separate percutaneous incisions. Osteotomy completion and pin placement are as described in the section 'Combined intraoral and extraoral approach'. Tissues are closed in layers, muscle periosteum and platysma 3/0 Vicryl, subcutaneous tissue 4/0 Vicryl and skin with 5/0 monofilament nylon. The device

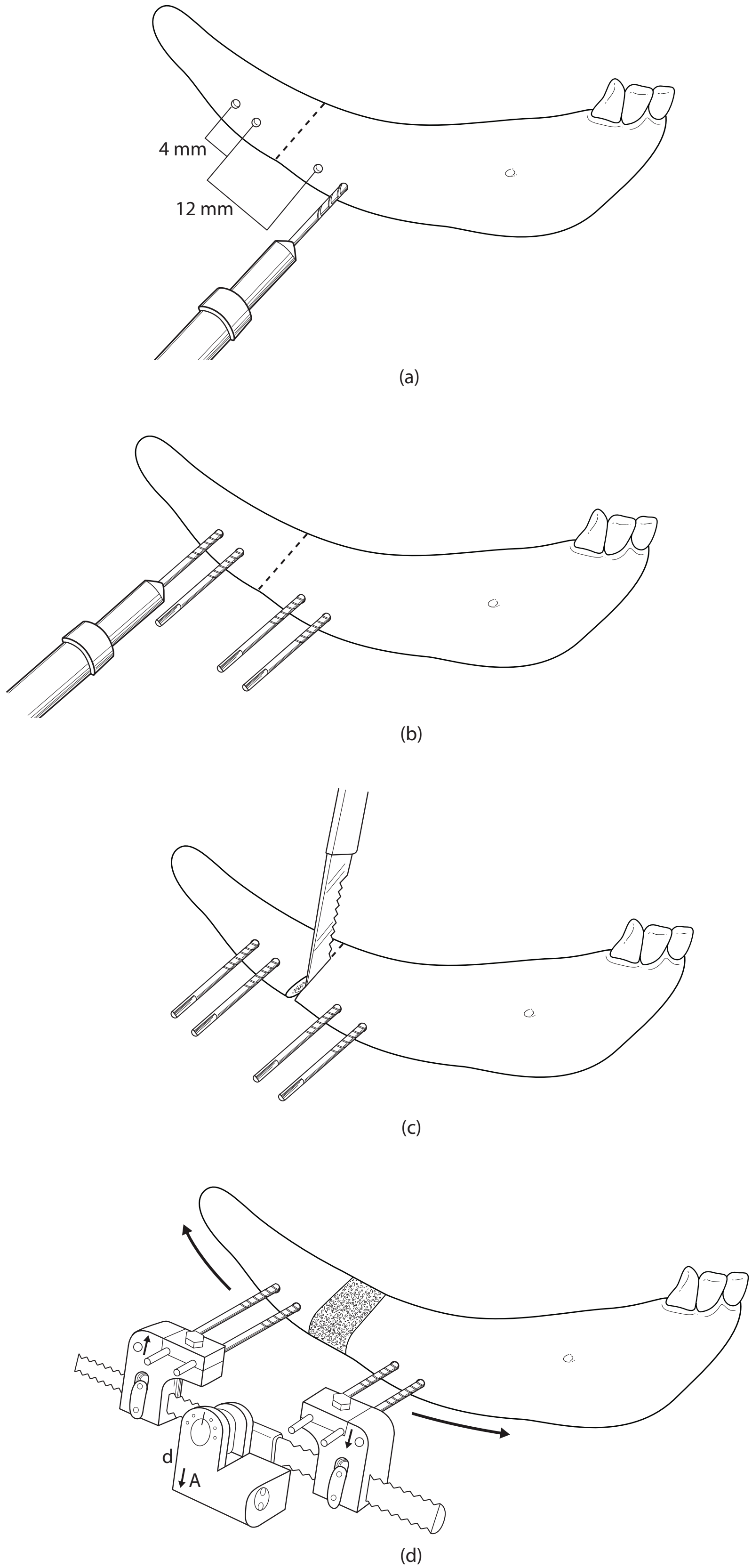


Figure 74.3 (a) External distraction device holes are drilled at least 6 mm away from the distraction osteotomy site and are placed 4 mm apart. The hole location determines the vector of distraction. (b) Fifty millimetre half pins are secured, two on either side of the osteotomy site. (c) The through-and-through osteotomy is created in the body ramus junction with care being taken to spare the inferior alveolar neurovascular bundle. (d) The application of the multiple planar distraction device (Howemedica Stryker Leibinger, Portage, Michigan).

activation is similar as described for intraoral devices. The distraction device removal should be accomplished with the same criteria as established for intraoral devices with adequate osseous fill of the distraction gap visualized on radiographs, CT scan and/or ultrasound. The device removal is usually carried out under local anaesthesia after the appropriate time of bony consolidation. This may range from 2 months in very young children to 5 months in adult patients.

POST-OPERATIVE CARE

If the patient has significant airway compromise with obstructive sleep apnoea, patient admission to the intensive care unit (ICU) with endotracheal intubation overnight or until ready for extubation is a consideration. Alternatively, extubation could be achieved if the patient is awake and alert and able to protect their own airway. Requirements for discharge from hospital are adequate pain control and PO intake, and otherwise stable recovery from anaesthesia and surgery. A 'minimal chew' soft diet is recommended for 6–8 weeks. In older children and adults, chlorhexidine 0.12% mouth rinse is a consideration during distraction device activation. Use of post-operative oral antibiotics requires judgement and is based on patient wound healing and clinical progress. Skin sutures, if used, are usually removed 7–10 days post-operatively (or longer) depending on wound tension during distraction.

DISTRACTION DEVICE ACTIVATION

Activation of the distraction device is typically started on post-operative day 5, although earlier distraction may be commenced in younger patients. The distraction rate is typically 1 mm a day divided in two or three activations. It is important that responsible adults or patients activate the devices properly. In patients from the age of birth to 2 years a distraction rate of 1.5–2 mm a day may be appropriate based on rapid ability to create new bone and concern with premature bony consolidation. Monitoring of distraction with periodic radiographs and visual inspection is appropriate one to two times per week. Frequent assessment during distraction allows recognition of complications or aberrant distraction vectors and is necessary to determine the completion of distraction. 3D vector adjustments can be made during distraction with selected multivector intraoral and extraoral DO devices (Figures 74.4 through 74.6). These are best done after approximately 10 mm of lengthening has occurred due to compression and stretching of the distraction regenerate. Vector alterations may be accomplished in sequential activations depending on the degree of distraction regenerate and the desired 3D changes.

Activation arms are typically removed under local anaesthesia and conscious sedation after the completion of the distraction activation. Device retention is based on the radiographic appearance of adequate ossification of the distraction regenerate which can range from 2 to 5 months. *Alternately, ultra sound can be used to assess the distraction regenerate.* Intraoral devices are better tolerated by the patient during the consolidation period. Intraoral or extraoral distraction device removal is accomplished under local anaesthesia with sedation as a separate procedure or under general anaesthesia particularly if a Le Fort I osteotomy and/or other surgical procedures are to be performed. Orthodontic intervention is frequently helpful in distraction cases to optimize occlusal outcomes.

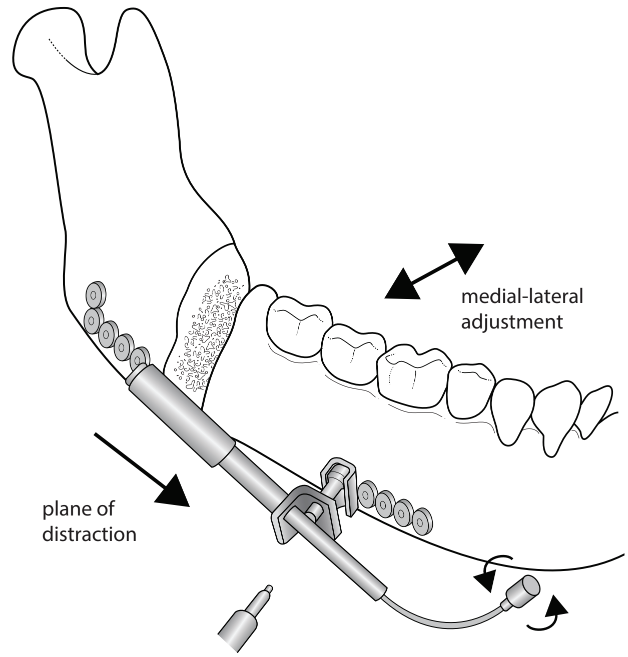


Figure 74.4 Bidirectional telescopic mandibular distractor with opportunity to distract longitudinally and mediolaterally.

COMPLICATIONS FROM DISTRACTION OSTEOGENESIS

Routine surgical problems can be addressed with appropriate post-surgical care including management of bleeding, haematoma, infection and wound dehiscence. Distraction device complications may include the following: loosening of the device secondary to inadequate stability which can result in fibrous union; failure of the device to activate due to device malfunction or premature bony consolidation; paraesthesia of the inferior alveolar, mental neurovascular bundle or lingual nerve which is usually temporary but on occasions can be permanent. Temporary cranial nerve VII palsy can occur with extraoral approaches but is rarely permanent. Skeletal relapse is uncommon if adequate distraction rates and consolidation times are utilized. Relapse may occur at the temporomandibular joint or the distraction osteotomy site.

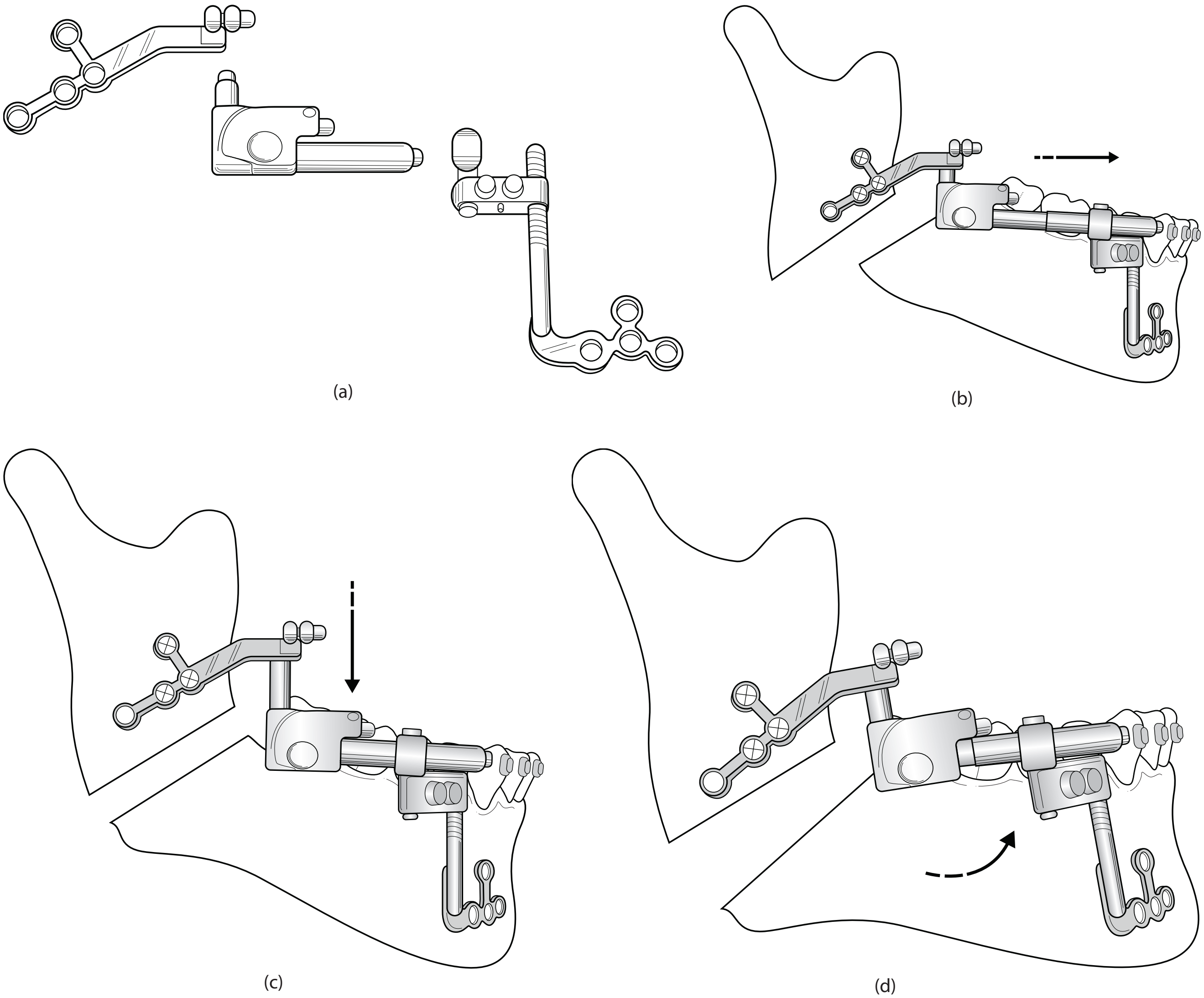


Figure 74.5 (a) Multiple axis intraoral distraction device (MDO-M distractor, Orthognathics GmbH, Zurich, Switzerland). (b) Schematic diagram showing distraction in a longitudinal direction. (c) Distraction vector adjustments in a superior/inferior plane. (d) Rotational movement of the distal segment with the distraction device.

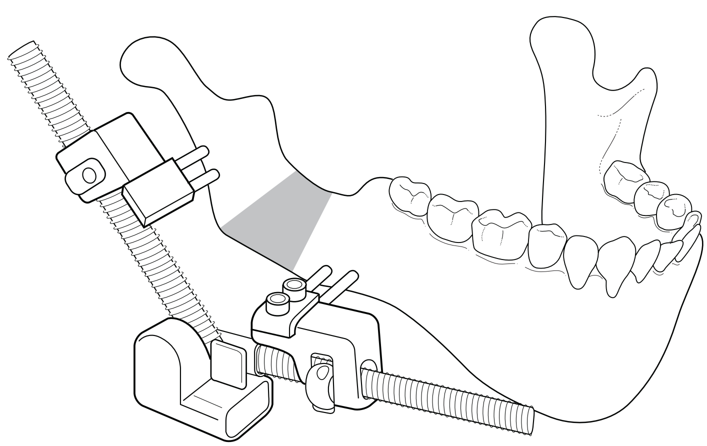


Figure 74.6 Multi-Guide II external distraction device shown on the paediatric mandible. Device can activate longitudinally, mediolaterally and superiorly/inferiorly (Stryker Leibinger, Portage, Michigan).

SUMMARY

This chapter has focused on the surgical technique of osteotomy and distraction device placement by intraoral and extraoral approaches for mandibular lengthening by DO. DO research and techniques are constantly evolving. This work is designed to supplement the reader's surgical knowledge of DO, but it would be expected that a responsible practicing surgeon would attend appropriate continuing education courses and lectures and have reviewed textbooks and important articles to provide the knowledge base to appropriately apply distraction techniques. In order to successfully apply distraction techniques, the practitioner should have a very good understanding of the biologic basis and principles of distraction as treatment modifications and adjustments are frequently required. DO is a powerful surgical technique and, when applied appropriately, distraction can be very rewarding to the patient and the practitioner.

Top tips

- DO techniques require proper understanding and application of the biologic principles of DO that are anatomically sound and age appropriate.
- DO device selection is based on available bone stock, ease of application, distance of DO and ability to adjust the distraction vector post-device placement.
- When performing the lateral cortex, inferior border and superior border osteotomies care is taken to ensure that these cuts do not encroach upon the inferior alveolar neurovascular bundle, facial artery and vein or the lingual nerve.
- When the platysma muscle is divided, care is taken to ensure identification and preservation of the marginal mandibular branch of the facial nerve.
- When securing the distraction device to the mandible, it is important to ensure the correct 3D distraction vector.
- The length of the mono and bicortical distraction device screws is dependent on the position of the inferior alveolar neurovascular bundle, teeth roots and developing tooth buds in infants and children.
- After completion of the osteotomy cuts, a wedging osteotome is tapped into place superiorly above the inferior alveolar nerve, and utilizing a torquing a motion a fracture is created through the remaining portion of the mandible.
- Distraction rates can range from 1 to 2 mm per day, divided in two to three activations per day, depending on the age of the patient.
- 3D vector adjustments can be made during distraction with selected multivector intraoral and extraoral DO devices and are best done after approximately 10 mm of lengthening has occurred.

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75

Maxillary distraction osteogenesis by intra-oral and extra-oral techniques

DAVID A WALKER

CONTENTS

INTRODUCTION

Distraction osteogenesis (DO) of the maxilla is a technique utilized to gradually lengthen the maxilla (predominantly the cleft maxilla) extensive distances. DO creates new bone without the need for bone grafting and donor site morbidity. Maxillary DO has many significant differences from mandibular DO. Anatomically, the maxilla is comprised of thin-walled membranous bone and distraction vectors are predominantly in a tangential vector from the osteotomy site as opposed to a perpendicular vector from the osteotomy site in the mandible. It is important to have a sound understanding of the biologic principles of DO and maxillary osteotomies when applying distraction techniques. There are a multitude of distraction devices including bone-borne, tooth-borne and intra-oral and extra-oral devices. The indications, advantages and disadvantages for maxillary DO are listed in Tables 75.1 through 75.3.

Table 75.1 Indications for maxillary distraction osteogenesis

Indications
Severe maxillary retrognathism
Cleft maxilla
Post-traumatic maxillary deficiency
Revision orthognathic surgery
Craniofacial syndromes including Apert's and Crouzon's syndrome

Table 75.2 Advantages of maxillary distraction osteogenesis

Advantages
Greater distance of maxillary lengthening compared with conventional maxillary osteotomies
No bone grafting or donor site morbidity
Greater stability compared with conventional orthognathic surgery
Overcomes the soft-tissue scarring and deficiencies (cleft patients)

Table 75.3 Disadvantages of maxillary distraction osteogenesis

Disadvantages
Requires two procedures; device placement osteotomy and device removal
Less occlusal control
Possible velopharyngeal incompetence with long distraction osteogenesis distances

PRE-OPERATIVE ASSESSMENT

A thorough history and clinical examination is appropriate with utilization of diagnostic imaging, including panoramic, posterior anterior and lateral cephalometric radiographs. Computed tomography (CT) scans with three-dimensional (3D) reconstructions of the maxilla are helpful. Dental study models mounted on a semi-adjustable articulator with prediction model surgery are of benefit. In selected instances, stereolithographic models may aid in treatment planning, osteotomy location and device contouring. Standardized 3D cephalometric prediction tracings are appropriate. In cleft maxilla patients, pre-operative speech assessment with nasopharyngeal airflow studies and/or fibre-optic nasopharygoscopy is important to identify borderline or frank velopharyngeal incompetence which may worsen with distraction. All clinical and diagnostic tools are utilized to plan out the proper 3D distraction vector selection and distance of distraction.

Maxillary DO device selection is based on available bone stock, ease of application, distance of DO and ability to adjust the distraction vector post-device placement. Intra-oral bone-borne devices have many advantages including good device stability and longer consolidation times, although extra-oral devices with cranial stabilization, in selected instances, have advantages such as longer distraction distances and ability to adjust distraction vector, but typically have shorter consolidation times.

ANAESTHESIA CONSIDERATIONS

Cleft palate patients with previous pharyngeal flap surgery require extra care and attention for nasal endotracheal intubation which may best be performed through fibre-optic approaches. Some craniofacial syndromes have choanal atresia and pre-operative CT scans and anaesthesia consultation would be appropriate. An anaesthesia approach can be either from an oral or naso-endotracheal approach. Occasionally, patients with severe maxillary retrognathism with sleep apnoea have tracheostomy tubes which can be utilized for inhalational anaesthesia.

OPERATIVE TECHNIQUE

The operative technique is similar to the classic Le Fort I osteotomy with some important modifications. After establishing general anaesthesia and administering appropriate antibiotic prophylaxis, attention is directed to the maxillary vestibule where local anaesthetic 2% lidocaine 1/100,000 epinephrine is infiltrated in the planned area of incision. Toxic dosages should be avoided, particularly in paediatric patients or those patients with cardiac anomalies. After allowing suitable time for haemostasis, a vestibular incision is made a minimum of 5 mm above the attached gingiva from zygoma to zygoma. It is desirable to leave significant labial attached gingiva pedicled to the maxilla. Adjustments in the incision location can be made in areas of cleft alveolus. The subperiosteal dissection is carried out exposing the piriform rim, the infraorbital nerve, the zygoma and a subperiosteal tunnel is carried out posteriorly back to the pterygomaxillary junction (Figure 75.1).

Osteotomy location is based on the need for adequate bone above and below the osteotomy site for application of the bone-borne distraction devices. At this point, the level of the osteotomy is marked with a 701 tapered fissure bur or with a reciprocating saw. All bone cuts or osteotomies are made with adequate soft-tissue retraction and copious saline irrigation. It is advisable at this time to contour and secure the left and right bone-borne distraction devices with two screws above and below the osteotomy site. It is important to have the vector of the distraction device close to the sagittal plane and not convergent. The distraction devices are now removed and stored in a safe sterile location. Typically, it is desirable to have approximately 5 mm of bone height above the apices of the dentition. The osteotomy location may have to be higher in younger patients where the developing canine teeth are unerupted. It is advantageous to have a step osteotomy in the zygoma region. The angle of the osteotomy will also control the vector of distraction and this can be adjusted to either inferiorly or superiorly depending on available bone stock (Figure 75.2a and b). External maxillary devices utilize a tooth-borne component which allows greater flexibility of osteotomy location. A Frier elevator is used to strip the nasal mucosa from the inferior and lateral aspect of the lateral nasal wall to the posterior extent of the nasal wall. A periosteal retractor is placed along the lateral nasal wall to prevent tearing of the tissues. An osteotomy is made with the reciprocating saw from the zygoma to the piriform

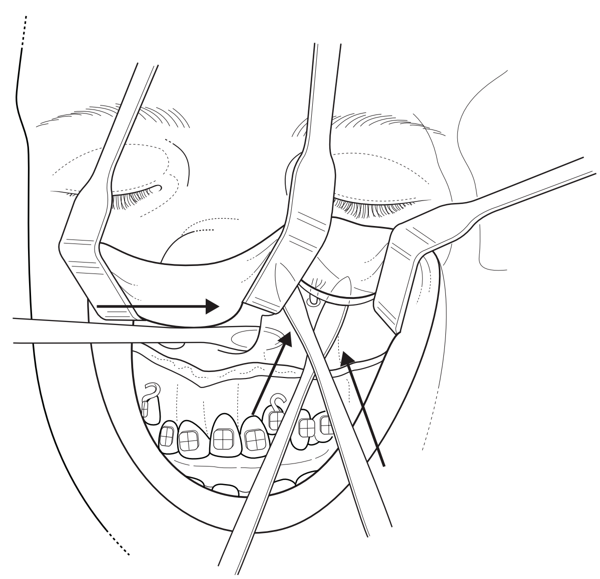

Figure 75.1 The subperiosteal dissection is carried out exposing the piriform rim, the infraorbital nerve, the zygoma and a subperiosteal tunnel is carried out posteriorly back to the pterygomaxillary junction.

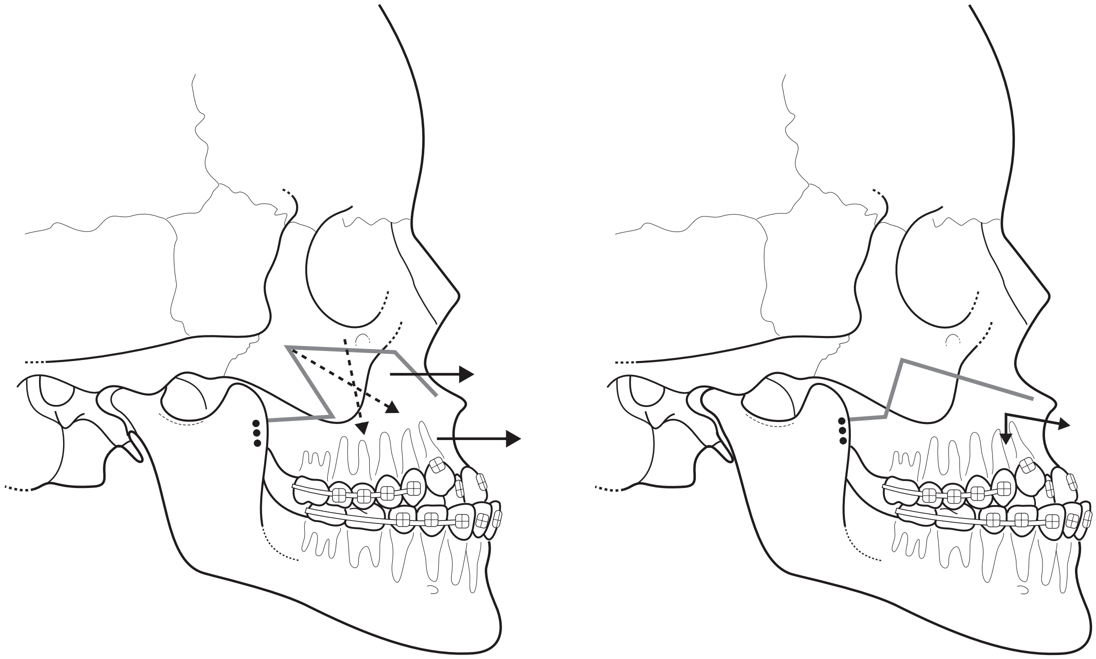

Figure 75.2 (a) The angle of the osteotomy is in the horizontal plane with a step at the zygoma for bone-borne distraction device. (b) The angle of the osteotomy will also control the vector of distraction and this is placed in a superior to inferior position allowing vertical lengthening of the maxilla during distraction, depending on available bone stock.

rim at the appropriate level. With the Langenback toe out retractor placed to the pterygomaxillary junction, the osteotomy is carried out posteriorly and inferiorly back to the pterygomaxillary junction (Figure 75.3a). The osteotomy is performed on the contralateral side of the maxilla care being taken to ensure it is symmetric. Next, the anterior nasal spine is dissected free and initial area of the attachment of the nasal septal cartilage to the maxilla is freed up. The nasal mucosa is stripped from the floor of the nasal cavity and the inferior aspect of septal cartilage. With adequate tissue retraction and a finger placed at the posterior nasal spine (oral side), the nasal septal osteotome is tapped with a mallet separating cartilaginous septum and vomer from the maxilla (Figure 75.3b). With a periosteal elevator in place protecting lateral nasal mucosa, a spatula osteotome is gently tapped along the lateral nasal wall until an increase in resistance is felt, ensuring the descending palatine neurovascular bundle is not transected (Figure 75.3c).

At this point, it is the author's preference to use the curved pterygoid osteotome to separate the maxilla from the pterygoid plates just prior to down fracturing the maxilla. It is important to place the osteotome near the inferior aspect of the pterygomaxillary junction and angled inferiorly in order to avoid the internal maxillary artery (Figure 75.3d). The operating surgeon controls the pterygoid osteotome and places a finger on the palatal aspect of the pterygomaxillary junction, while the surgical assistant strikes the osteotome with the mallet. Subsequently, the maxilla is digitally down fractured with pressure on the anterior maxilla and midface. Extensive mobilization is not required, just enough to free up the maxilla (Figure 75.3e). If difficulty is experienced in mobilizing the maxilla, recheck all osteotomy cuts, and if necessary, the Rowe disimpaction forceps can be placed on the nasal floor below nasal mucosa and on the hard palate to free up the maxilla. Care is taken to avoid damage to the incisors.

It is advisable to remove the sinus mucosa from the inferior aspect of the maxillary sinus and to remove any bony irregularities along the Le Fort I cut that may impede distraction movement (Figure 75.3f). Next, the bone-borne distraction devices can be placed and secured with 1.5–2.0 mm self-tapping screws of appropriate length. The devices should be activated a few millimetres to ensure maxillary movement then backed down to zero (Figures 75.4a and b and 75.5a and b). When using external distractors, there is no bone-borne stabilization and if there is significant mobility of the maxilla, a transosseous 3/0 gut suture can be placed in the piriform area. If there is concern with respect to alar base flaring, an alar base suture with 2/0 vicryl can be placed. Copious saline irrigation is carried out, haemostasis is obtained and tissues are closed in a two-layer fashion with 3/0 vicryl interrupted horizontal mattress sutures in the muscle periosteum layer. The mucosal incision is closed with 4/0 monofilament nylon horizontal mattress sutures for wound eversion then 4/0 chromic gut running suture for watertight closure. The incision may have considerable tension on it during long distraction distances. It is typical to have the device activation arm exit through the incision line or through a

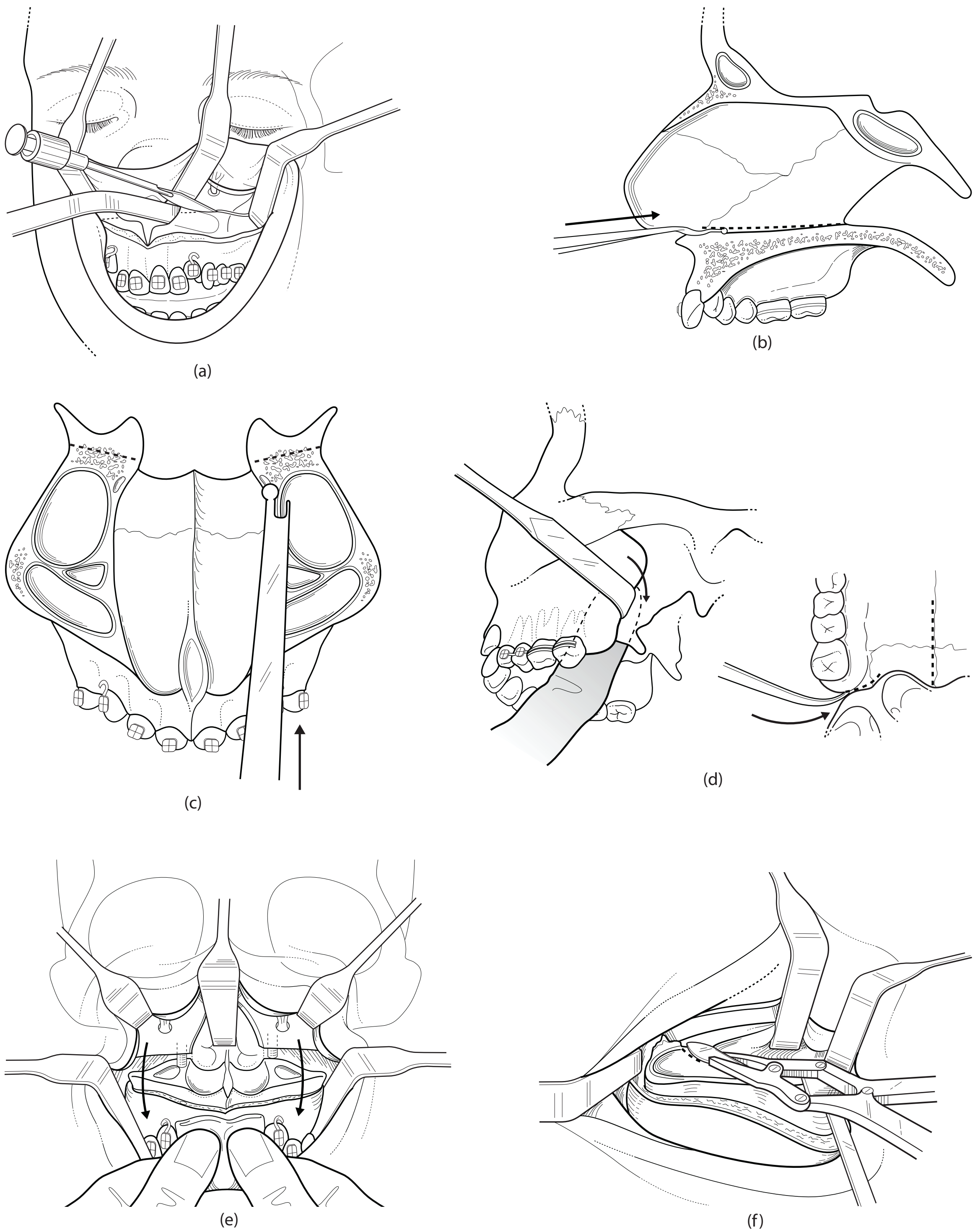

Figure 75.3 (a) A periosteal retractor is placed along the lateral nasal wall to prevent tearing of the tissues. An osteotomy is made with the reciprocating saw from the zygoma to the piriform rim at the appropriate level. With the Langenback toe out retractor placed to the pterygomaxillary junction, the osteotomy is carried out posteriorly and inferiorly back to the pterygomaxillary junction. (b) With adequate tissue retraction and a finger placed at the posterior nasal spine (oral side), the nasal septal osteotome is tapped with a mallet separating cartilaginous septum and vomer from the maxilla. (c) With a periosteal elevator in place protecting lateral nasal mucosa, a spatula osteotome is gently tapped along the lateral nasal wall until an increase in resistance is felt ensuring the descending palatine neurovascular bundle is not transacted. (d) It is important to place the osteotome near the inferior aspect of the pterygomaxillary junction and angled inferiorly in order to avoid the internal maxillary artery and have a finger palpating the pterygomaxillary junction from the oral side. (e) The maxilla is digitally down fractured with pressure on the anterior maxilla and midface. Extensive mobilization is not required, just enough to free up the maxilla. (f) It is advisable to remove the sinus mucosa from the inferior aspect of the maxillary sinus and to remove any bony irregularities along the Le Fort I cut that may impede distraction movement.

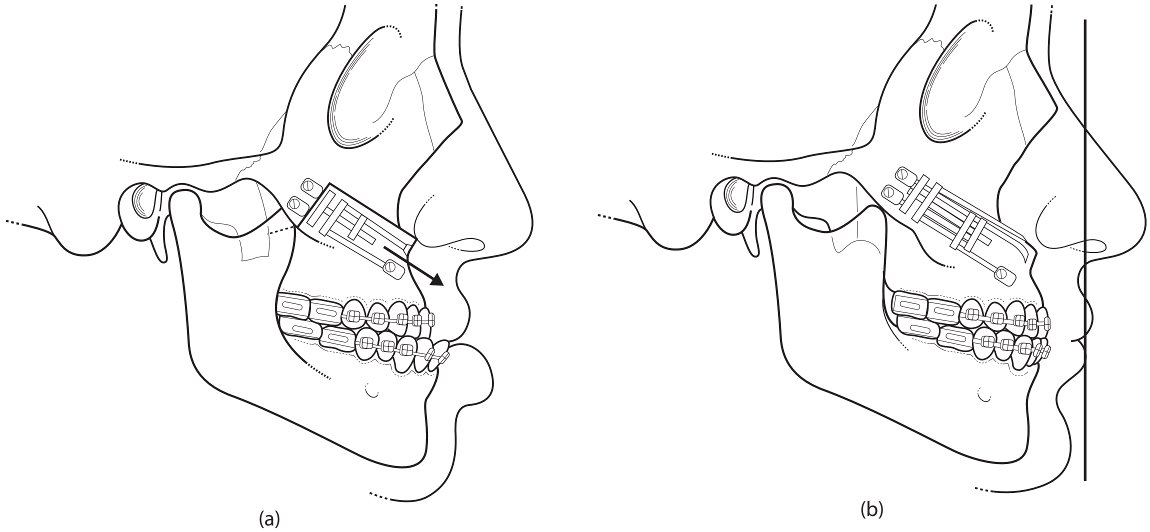

Figure 75.4 (a and b) Bone-borne distractor after osteotomy and placement, and after the completion of distraction. (Courtesy of Dynaform, Stryker, Leibinger Inc, Kalamazoo, MI.)

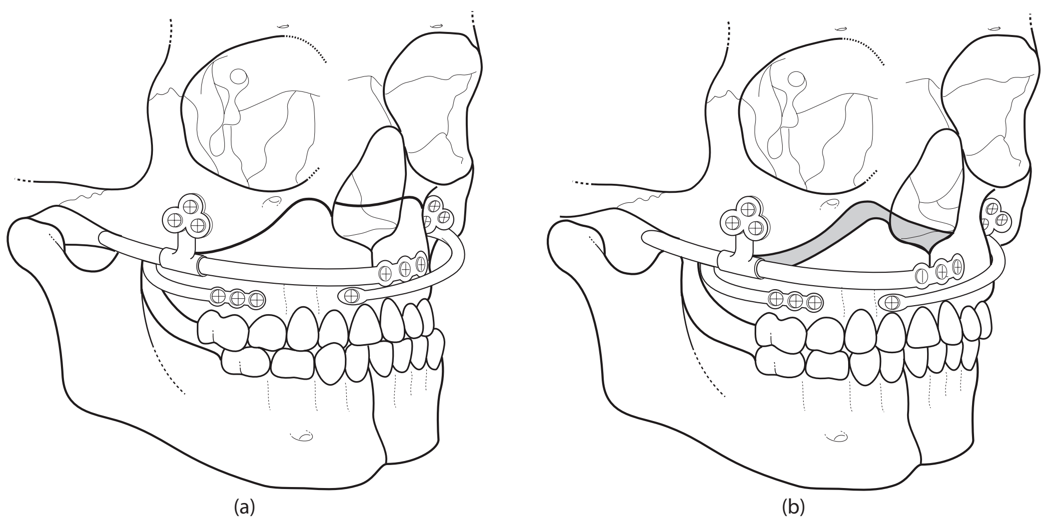

Figure 75.5 (a and b) Bone-borne distractor in paediatric patient after osteotomy and placement, and after the completion of distraction. (Courtesy of Zurich Pediatric Maxillary Distractor, KLS Martin Jacksonville, FL.)

separate transmucosal stab incision depending on device position.

External maxillary distraction devices have a tooth-borne component which is usually placed by the orthodontist pre-operatively or intra-operatively and are attached to the external distraction framework connected to the halo frame (Figures 75.6 and 75.7a and b). Alternatively, bone plates can be attached to the maxilla and attached via stainless steel wire to the external vertical bar (Figure 75.8). Placement of the halo frame should be based on bone quantity and quality measured on pre-operative CT scan. The halo frame should be parallel to Frankfort horizontal plane and should be sized to fit not more than approximately 2 cm from the patient's head and be placed far enough anterior to allow the maxillary distance of distraction. The screws should penetrate the scalp and calvarium into the outer cortex only. Three to four screws per side is desirable, 2–4 cm above the helix of the ear, avoiding the thin bone of the temporal fossa. The vertical component of the external system should be in the midline parallel to the facial plane and is attached to the orthodontic intra-oral device (Figures 75.7a and b and 75.8).

POST-OPERATIVE CARE

If the patient has significant pre-operative airway compromise, patient admission to the ICU with endotracheal intubation overnight, or until ready for extubation, is a

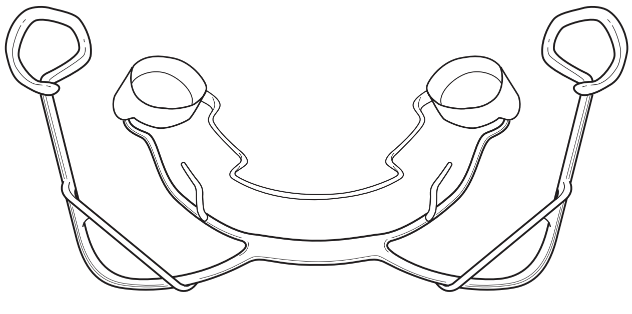

Figure 75.6 Orthodontic device to be cemented on to molars with external arms to be connected to external distraction device.

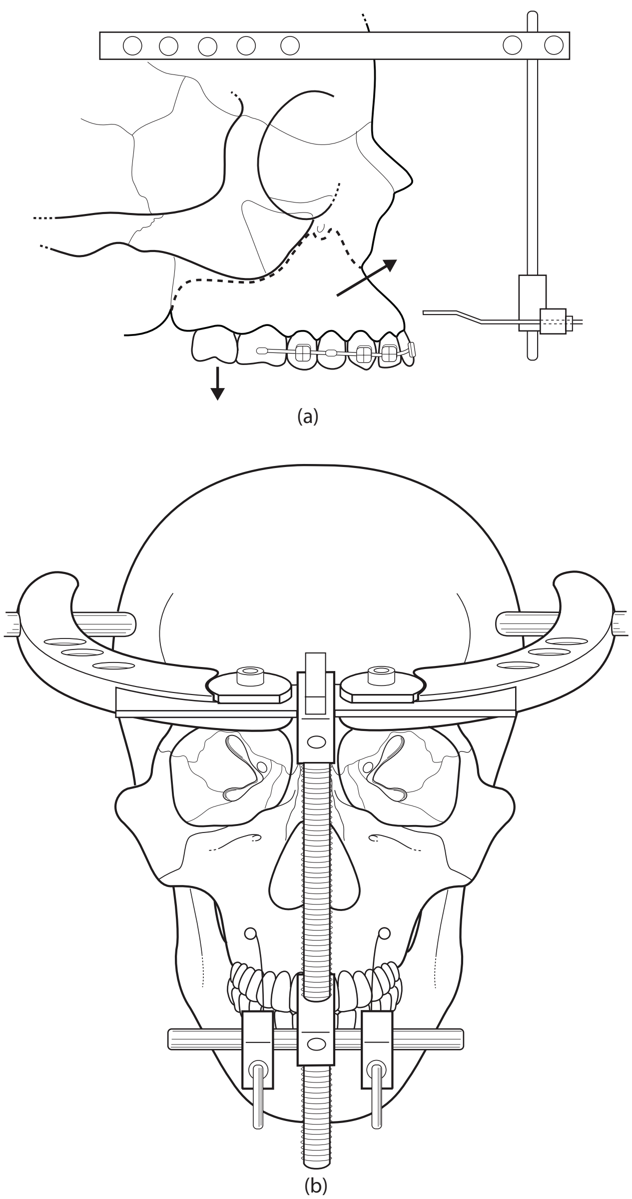

Figure 75.7 (a and b) Rigid external distraction (RED) device with attachment to orthodontic devices. (Courtesy of KLS Martin, Jacksonville, FL.)

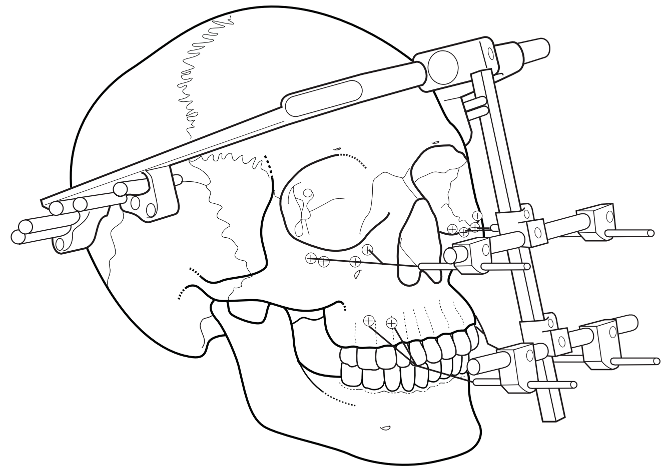

Figure 75.8 Halo frame external distractor with bone plate attachments on the maxilla and midface. (Courtesy of BLUE Device Multi-Vector Distraction, Biomet Microfixation, Jacksonville, FL.)

consideration. Alternatively, extubation could be achieved if the patient is awake and alert and able to protect their own airway. Periodic nasal clearing of significant blood clots with a Q tip and hydrogen peroxide may be appropriate. Topical or systemic sinus decongestants can be used depending on patient age and clinical need. Requirements for discharge from hospital are adequate pain control and p.o. intake, and otherwise stable recovery from anaesthesia and surgery. A ‘minimal chew’ soft diet is recommended for 6–8 weeks. In older children and adults, chlorhexidine 0.12% mouth rinse is a consideration during distraction device activation. Use of post-operative oral antibiotics requires judgement and is based on patient wound healing and clinical progress. No specific care is required for halo screws.

DISTRACTION DEVICE ACTIVATION, REMOVAL

Activation of the distraction device is typically started on post-operative day 5–7, although earlier distraction may be commenced in younger patients. The distraction rate is typically 1 mm per day divided in two or three activations. It is important to have responsible adults or patients to activate the devices appropriately. Monitoring of distraction with periodic radiographs and visual inspection is appropriate one to two times per week. Frequent assessment during distraction allows recognition of complications or aberrant distraction vectors and is necessary to determine the completion of distraction. 3D vector adjustments can be made during distraction with selected extra-oral DO devices. Vertical vector alterations may be accomplished in sequential activations depending on the degree of distraction regenerate and the desired 3D changes. If orthodontic appliances are in place, class III and/or vertical elastics may aid in occlusal correction.

Activation arms are typically removed under local anaesthesia and conscious sedation after the completion of the distraction activation. In devices with non-removable activation arms, tissues are monitored periodically. Device removal is accomplished under local anaesthetic and sedation and is based on the radiographic appearance of adequate ossification of the distraction regenerate which can range from 6 weeks to 5 months. Intra-oral devices are better tolerated by the patient during the consolidation period. If external devices are removed after shorter consolidation times, an orthodontic facemask appliance should be worn at night time for an additional 2–3 months to minimize relapse. Orthodontic intervention is frequently helpful in distraction cases to optimize occlusal outcomes.

COMPLICATIONS FROM MAXILLARY DISTRACTION OSTEOGENESIS

Routine surgical problems can be addressed with appropriate post-surgical care including management of bleeding, haematoma, infection and wound dehiscence. Distraction device complications may include the following: loosening of the device secondary to inadequate stability and failure of the device to activate (breakage, activation gear malfunction). Surgical intervention with replacement or restabilization of the DO device would be appropriate. Aberrant distraction vectors can produce occlusal problems which can be remedied with orthodontic treatment with elastic traction or on occasion with mandibular surgery. Premature bony consolidation is rare, but occasionally fibrous union can occur and may be treated with application of bone plate fixation and or autologous bone grafting. Paraesthesia of the infraorbital nerve is usually temporary but on occasion can be permanent. Skeletal relapse at the distraction osteotomy site is uncommon if adequate distraction rates and consolidation times are utilized. Velopharyngeal incompetence is documented in cleft maxilla after long distraction distances and may require a pharyngeal flap to correct speech problems. Intracranial pin migration with halo frame (particularly with craniofacial syndromes or previous cranial vault surgeries) has been reported.

Top tips

- Maxillary distraction techniques require proper understanding and application of the biologic principles of DO that are anatomically sound and age appropriate.
- Anatomically, the maxilla is comprised of thin-walled membranous bone and distraction vectors are predominantly in a tangential vector from the osteotomy site as opposed to a perpendicular vector from the osteotomy site in the mandible.
- Maxillary DO internal or external device selection is based on available bone stock, ease of application, distance of DO, osteotomy location and ability to adjust the distraction vector post-device placement.
- In cleft maxilla patients, pre-operative speech assessment with nasopharyngeal airflow studies and or fibre-optic nasopharygoscopy is important to identify borderline or frank velopharyngeal incompetence which may worsen with distraction.
- Cleft palate patients with previous pharyngeal flap surgery require extra care and attention for nasal endotracheal intubation which may best be done through fibre-optic approaches.
- Maxillary osteotomy location is based on the need for adequate bone above and below the osteotomy site for application of internal bone-borne distraction devices and can be placed in a higher position with external DO devices.
- When securing the internal distraction devices to the maxilla, it is important to ensure the correct 3D distraction device vector close to the sagittal plane and not convergent.
- The external distractor halo frame should be parallel to Frankfort horizontal plane, should be sized to fit and not be more than approximately 2 cm from the patient's head and should be placed far enough anterior to allow the maxillary distance of distraction.
- When securing the halo frame with screws, avoid the thin bone of the temporal region and select CT scan-guided screw position in craniofacial syndromes or those patients with previous cranial surgery.
- Distraction rates can range from 1 to 2 mm per day, divided into two to three activations per day, depending on the age of the patient.
- 3D vector adjustments can be made during maxillary distraction with selected multivector extra-oral DO devices.

SUGGESTED READINGS

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Surgical management of craniosynostosis

G E GHALI and JENNIFER E WOERNER

CONTENTS

INTRODUCTION

Craniosynostosis is a term first coined by Virchow to describe the premature fusion of one or more cranial sutures resulting in an abnormal head shape. Because of this stenosis, growth perpendicular to the suture line is restricted with compensatory overgrowth at the remaining patent suture lines. Most forms of craniosynostosis are random and non-syndromic, occurring as isolated incidences and are not associated with any other conditions or deformities. In the United States, non-syndromic craniosynostosis occurs in approximately 1 in 1000 live births. Diagnosis is based on both clinical and radiographic evaluations. The clinical evaluation involves the palpation of the skull for any movement, ridging and absence or presence of the anterior and posterior fontanelles. Quantitative measurements of the superior orbital rims, relative to the most anterior aspect of the cornea, are also useful in treatment planning of superior orbital rim advancements. The radiographic evaluation of craniosynostosis is used to quantitatively define aberrant anatomy, plan surgical procedures and provide a means to demonstrate to parents the difference between stenosed and nonstenosed sutures. Computed tomography provides the craniofacial team with a baseline record, a means of surgical planning and a modality to document surgical changes in vivo thereby allowing longitudinal comparisons.

INDICATIONS

Functional considerations

- *Inhibition of brain growth:* Although the neurodevelopmental morbidity of non-syndromic craniosynostosis is not fully understood, children manifesting non-syndromic synostosis exhibit significant speech, behavioural and cognitive abnormalities compared with the general population.
- *Intracranial hypertension:* Varying degrees of intracranial hypertension, decreased cerebral perfusion pressure and episodic respiratory obstruction are documented complications associated with complex craniosynostosis. Intracranial hypertension of greater than 15 mm Hg develops in 13% of single suture synostosis and 42% of multisuture synostosis patients. Multisuture stenosis is accompanied by hydrocephalus in 10% of cases. Acute intracranial hypertension manifests as papilloedema, headache and nausea/vomiting; chronic signs are optic and cerebral atrophy.
- *Neuromotor development:* In a series of scaphocephalic patients, auditory short-term memory and language developmental impairment persisted following cranial vault corrective surgery. Neuromotor development improves with surgery. Functional studies suggest regional cerebral circulation improvement following corrective surgery for unilateral or simple craniosynostosis.

- *Visual/auditory impairment:* Glucose metabolism and brain function relative to visual development and spatial coordination significantly improve following corrective surgery for single-suture synostosis. Although posterior plagiocephaly comprises less than 3% of all isolated synostosis cases, diagnosis is critical because of its relationship to significant hemifield visual asymmetry. The degree of visual field impairment does not correlate to the degree of deformation or the laterality of the defect.

Aesthetic and psychosocial considerations

- Correction of the deformity provides a more normal contour to the naso-orbital region, supraorbital unit and cranial vault. Children who fail to undergo timely repair of craniosynostotic deformities often represent due to social hardships and parental concerns for their child's successful integration into society.

CLASSIFICATION AND CHARACTERISTICS

- Sagittal synostosis (Figure 76.1)
  - Scaphocephaly
  - Transverse skull narrowing
  - Anteroposterior skull elongation
  - Premature sagittal fusion
  - Represents 50% of synostosis cases in the United States
- Unilateral coronal synostosis (Figure 76.2)
  - Frontal plagiocephaly
  - Asymmetric skull shape
  - Forehead flattened and retropositioned on abnormal side
  - Premature unilateral coronal fusion
  - Differential diagnosis includes infant positioning, moulding, congenital torticollis and lambdoid synostosis
  - Represents 20% of synostosis cases in the United States
- Bilateral coronal synostosis (Figure 76.3)
  - Brachycephaly
  - Sagittal skull shortening
  - Lower forehead
  - Recessed supraorbital bar
  - Excessive transverse dimension of forehead
  - Most common syndrome associated
  - Premature bilateral coronal fusion
  - Represents 20% of synostosis cases in the United States
- Metopic craniosynostosis (Figure 76.4)
  - Trigonocephaly
  - Triangular skull

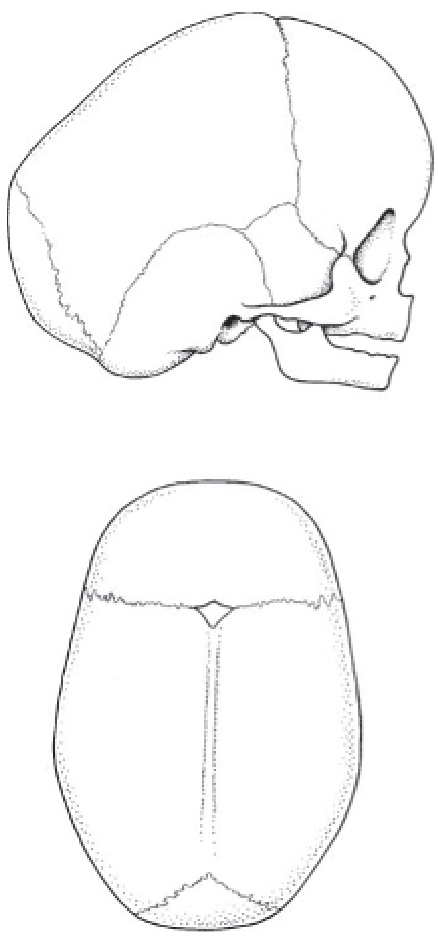


Figure 76.1 Sagittal synostosis in lateral and superior views.

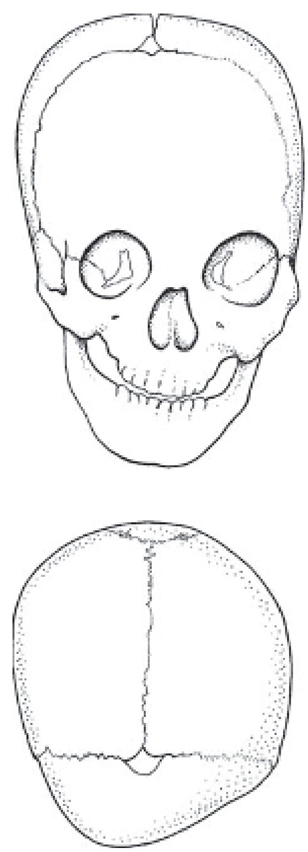


Figure 76.2 Left anterior plagiocephaly in frontal and superior views.

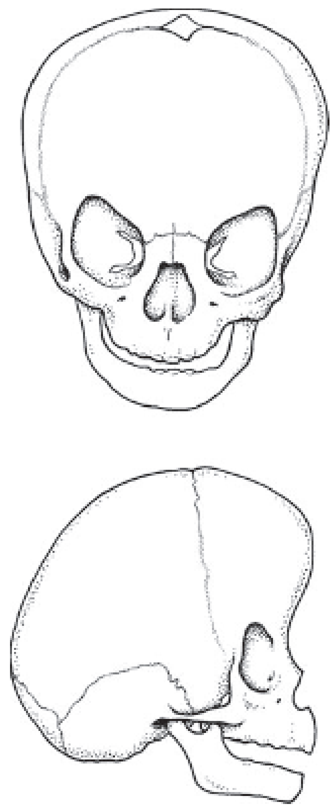


Figure 76.3 Bicoronal synostosis in frontal and superior views.

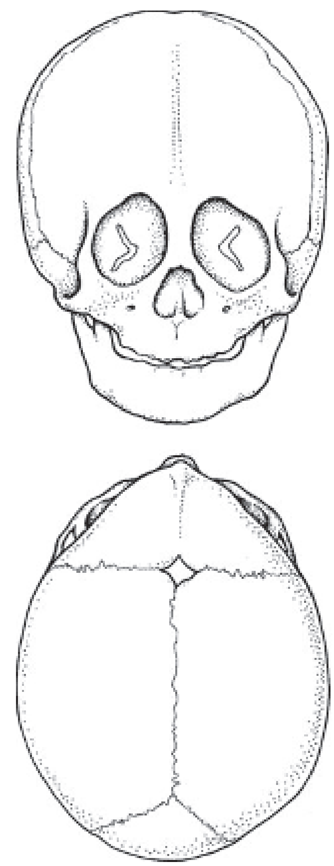


Figure 76.4 Metopic synostosis in frontal and superior views.

- Prominent midline keel
- Relative
- Hypotelorism
- Premature metopic fusion
- Represents 10% of synostosis cases in the United States

TIMING OF SURGERY

Brain volume in the normally developing child nearly triples in the first year of life growing from 350 to 950 g; at 24 months, the brain reaches 1250 g with the adult brain weighing 1350 g. Rapid brain growth requires that the cranial vault achieve 80% of the adult size by birth and readily expands until 3 years of age. A good indication of cranial growth can be ascertained by skull circumference measurements. Low figure measurements for any age group may be a sign of craniosynostosis or microcephaly. The cephalic ratio is defined as the relationship between the bitemporal width and the anteroposterior length. The normal length to width ratio is 2:3. A lower ratio may be suggestive of sagittal synostosis. In craniosynostosis, premature suture fusion is combined with continued brain growth. Precise timing remains controversial and individualized. We prefer surgical repair between 4 and 8 months of age, whereas other centres have reported good results when treatment is completed between 2.5 and 3 years of age. Timely surgical intervention allows for rapid frontal lobe growth which supports the forehead and supraorbital ridge. Additionally, at this age the cranium is highly malleable and therefore easier to contour. Children over 1 year of age have thicker bone which is more difficult to modify. Although some patients may require multiple staged surgical procedures, early intervention may have a positive effect on facial growth and result in a lessening of the facial deformity as the child grows.

OPERATIVE TECHNIQUE

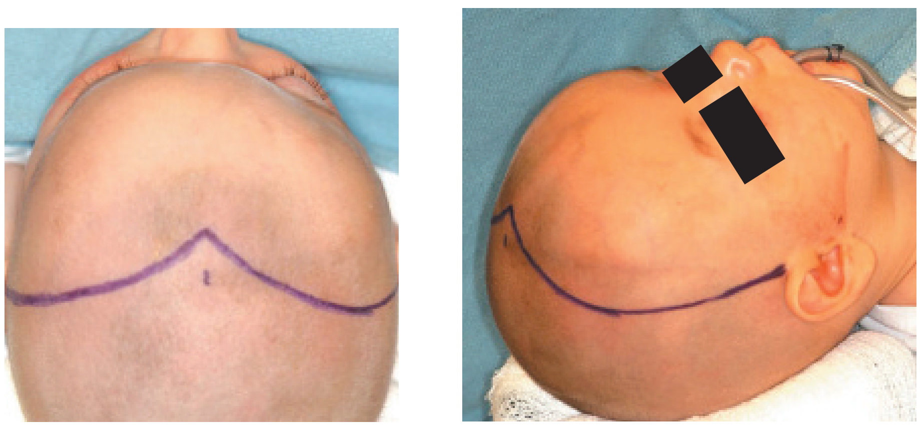
Pre-operative preparation

The pre-operative assessment should include a complete blood count and a basic metabolic panel. It is imperative that the child be cross-matched for at least two units of packed red blood cells, fresh frozen plasma and platelets before surgery. The blood must be available in the operating theatre before incision. Central venous catheterization and large-bore peripheral venous access greatly assist the anaesthesia team in monitoring and resuscitation associated with significant blood loss and fluid shifts that may occur during the operation. In addition to routine

electrocardiography, peripheral oxygen saturation and capnography monitoring, arterial line placement and precoridal Doppler monitoring are useful adjuncts in patient monitoring. All fluids and blood products are warmed. It is critical that the operating theatre should be kept warm during induction, patient preparation and draping to ensure the maintenance of normal body temperature.

Unilateral coronal synostosis

- The patient is positioned supine with the head secured on a Mayfield headrest. Via a coronal incision, a subperiosteal anterior scalp flap is elevated along with the temporalis muscle bilaterally. Pre- or postauricular extensions may be utilized if needed (Figure 76.5a and b).
- Bilateral subperiosteal reflection extends to the periorbital and zygomaticotemporal regions anteriorly whilst maintaining the attachment of the medial canthal tendons. Posteriorly, the scalp flap is reflected midway between the coronal and lambdoid sutures (Figure 76.6). Markings for the bifrontal craniotomy and fronto-orbital bar/bandeau are indicated (Figure 76.7).
- Bifrontal craniotomy using the Midas Rex drill (Medtronic, Minneapolis, MN) developing a 1.5 cm bandeau (Figure 76.8).
- Retraction of the frontal and temporal lobes of the brain facilitates superior orbital and temporal osteotomies. Bilateral tongue-in-groove (tenon) extensions developed via a reciprocating saw to the level of pterion (Figure 76.9).
- Intracranial retraction of frontal lobes (Figure 76.10) as well as intraorbital retraction of the periorbita (Figure 76.11) is necessary to achieve the anterior skull base osteotomy. One may tailor the level of the lateral orbital rim osteotomy based on aesthetic needs.
- The removed bandeau is adjusted bilaterally via the removal of wedges from the recessed side and scoring of the over-projected side (Figure 76.12a). The bandeau is recontoured by bending the recessed side and straightening the over-projected side (Figure 76.12b).
- Barrel-staving osteotomies are placed in the parietal and/or temporal bones as needed for reshaping (Figure 76.13).
- Resorbable plates and screws are utilized for stabilization of the bandeau and forehead (Figure 76.14a and b).



(a) (b)

Figure 76.5 (a) Superior and (b) lateral views of coronal markings in preparation for plagiocephaly correction.

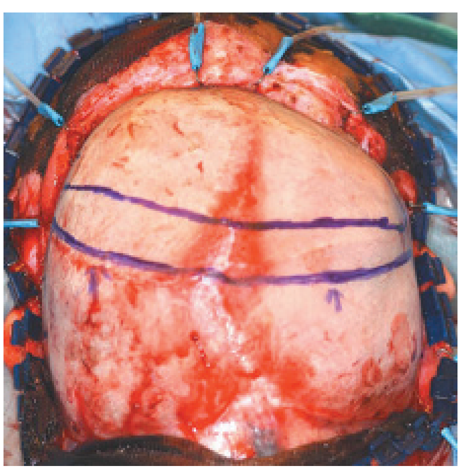


Figure 76.6 Superior view demonstrating extent of subperiosteal reflection, as well as degree of right-sided anterior plagiocephaly.

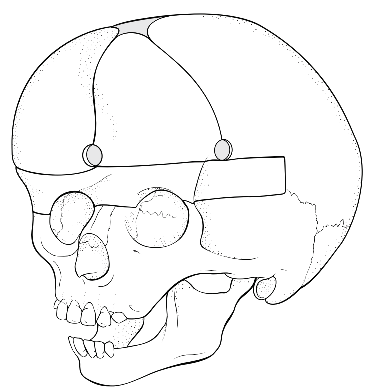


Figure 76.7 Bur holes in preparation for bifrontal craniotomy at the level of the supraorbital region.

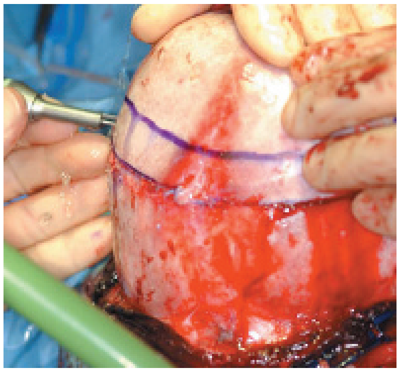


Figure 76.8 Neurosurgeon performs craniotomy using Midas Rex drill.

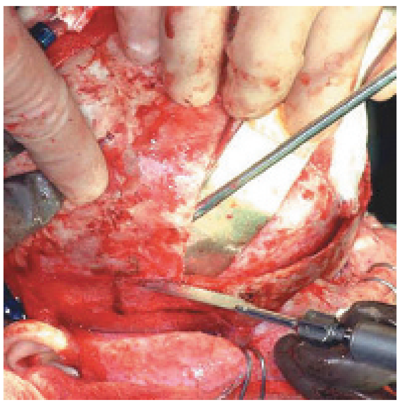


Figure 76.9 Reciprocating saw is utilized to perform bifrontal tenon extension osteotomies.

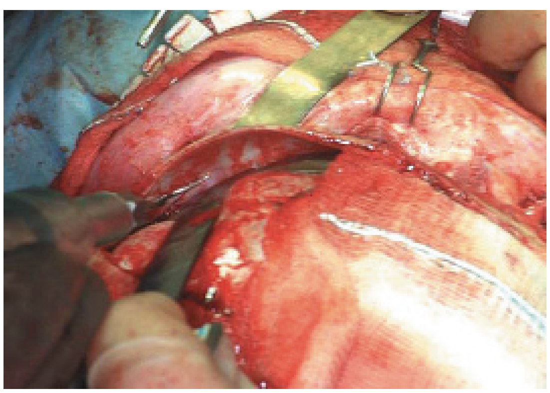


Figure 76.10 Intracranial retraction to expose anterior cranial base for osteotomy.

Bilateral coronal synostosis

- Surgical positioning, approach and osteotomy design is similar to that already described for plagiocephaly repair. Sites of osteotomies bilaterally as indicated (Figure 76.15).
- Following osteotomies, reshaping and fixation of the bandeau and forehead are undertaken (Figure 76.16).

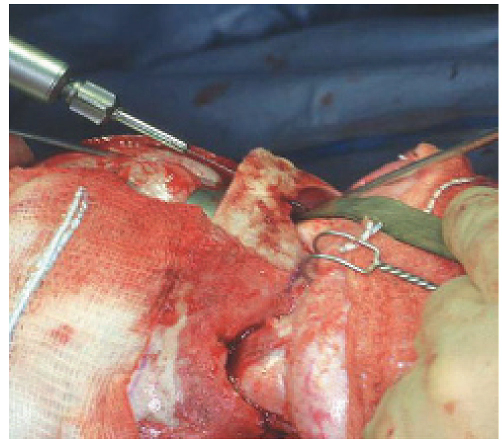


Figure 76.11 Combined intracranial and intraorbital retraction to complete the anterior cranial base osteotomy along the orbital roof.

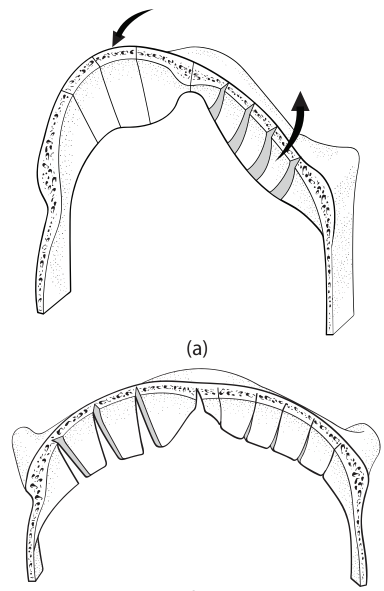


Figure 76.12 Removed bandeau (a) before and (b) after wedge and scoring osteotomies.

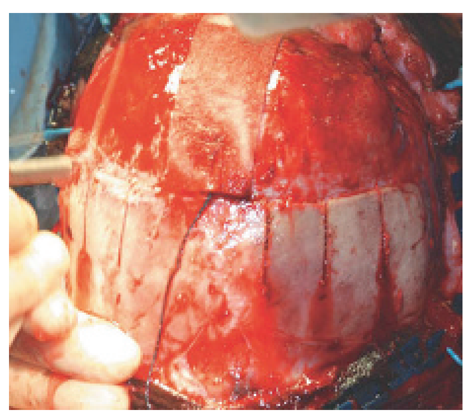
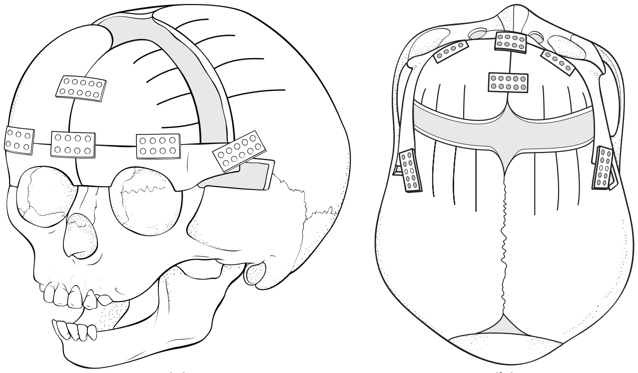


Figure 76.13 Barrel-staving osteotomies achieved via Midas Rex or reciprocating saw to impart plasticity to the bone.



(a) (b)

Figure 76.14 (a) Oblique and (b) superior views following resorbable plate fixation.

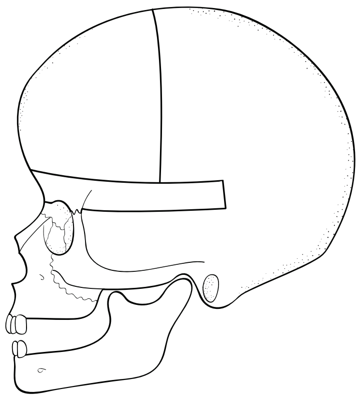


Figure 76.15 Lateral view of proposed osteotomy design for repair of bicoronal synostosis.

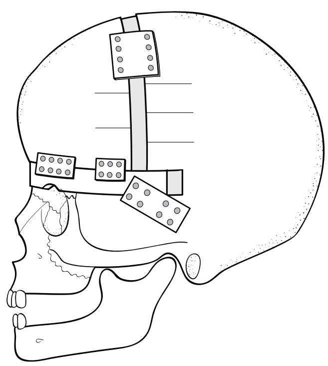
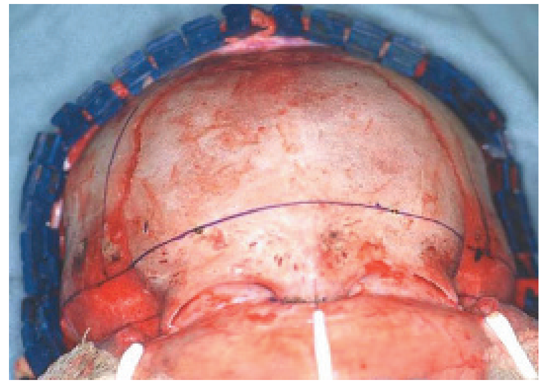
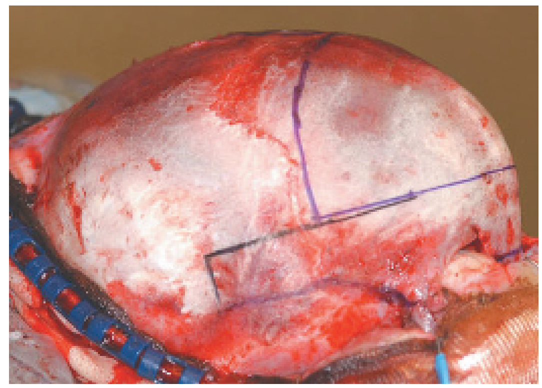


Figure 76.16 Lateral view after resorbable plate fixation.

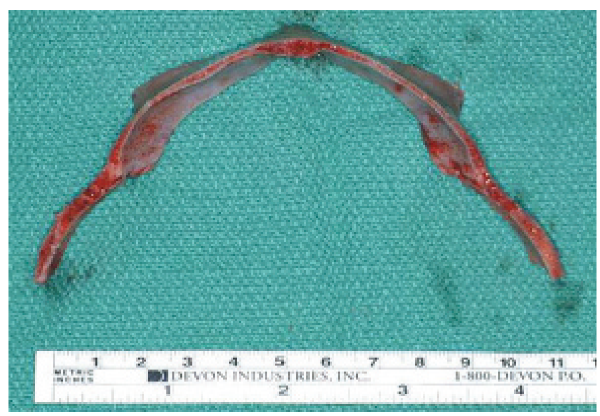


(a)

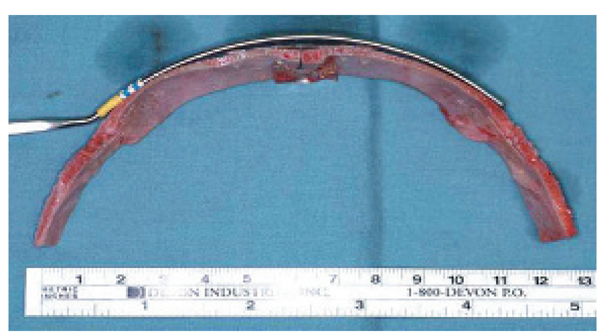


(b)

Figure 76.17 Proposed osteotomy markings from (a) frontal and (b) lateral views.



(a)



(b)

Figure 76.18 Bandeau (a) before and (b) after reshaping and resorbable plate fixation.

Metopic synostosis

- The surgical positioning, approach and initial osteotomy design is similar to that already described. The site of osteotomies of the anterior cranial vault and superior orbital rims from frontal (Figure 76.17a) and lateral (Figure 76.17b) views.
- Superior view of bandeau before (Figure 76.18a) and after (Figure 76.18b) reshaping.

- The bandeau is sometimes vertically split at the midline and an autogenous cranial bone graft placed to correct true hypotelorism (Figures 76.19 and 76.20).
- Assessment of the gap between the bandeau and anterior cranial base assists in determining symmetric correction and bitemporal expansion (Figure 76.21).
- Barrel staving is often needed to widen the temporal region before final anterior cranial vault reshaping and fixation (Figure 76.22a and b).

Sagittal synostosis

- Premature closure of the anterior two-thirds of the sagittal suture requires formal total reshaping of the cranial vault, with or without superior orbital rim shaping. When the entire sagittal suture is fused, a combination of both anterior and posterior approaches may be necessary. For children over 12 months of age or children with the need for upper orbital reconstruction, we prefer the supine position at one operative setting, or rarely, in two stages with posterior reconstruction preceding anterior treatment by 4–6 months.
- The forehead is tilted posteriorly, and the occiput is tilted anteriorly thereby reducing the anterior–posterior dimension; resorbable fixation is used to secure the segments. Barrel staving as well as interchanging of the temporal segments helps widen the transverse dimension (Figure 76.23).
- The patient must be prone when the posterior half of the sagittal suture is involved with protection of the airway and globes. Unless a significant concomitant supraorbital deformity exists, we prefer to treat full sagittal suture stenosis via total cranial vault reshaping at one operative setting with the patient in the prone position (Figure 76.24).
- Intraoperative (Figure 76.25a) and schematic (Figure 76.25b) pre-operative superior views of the proposed osteotomy sites for total cranial vault reshaping without orbital osteotomies.

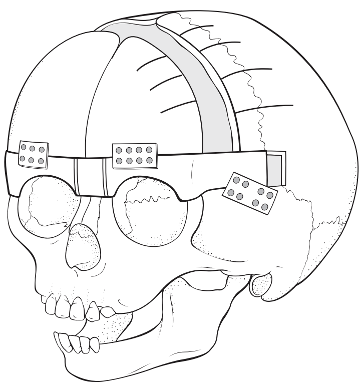


Figure 76.19 Fixation following metopic synostosis correction from an anterior view.

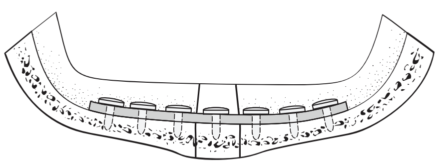


Figure 76.20 Internal resorbable plating of the bandeau at the midline with autogenous bone grafting.

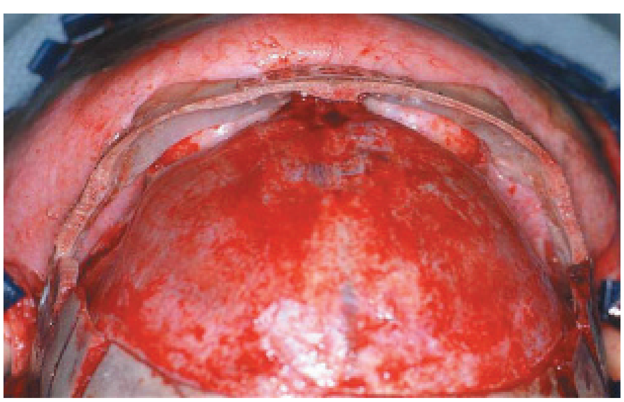
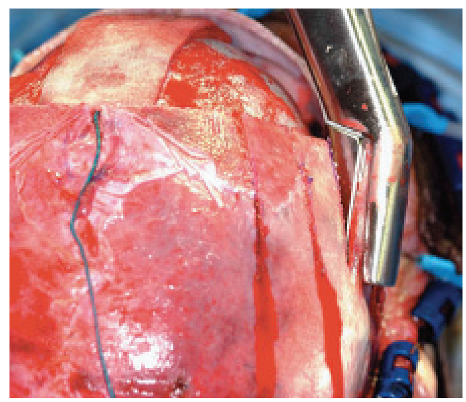
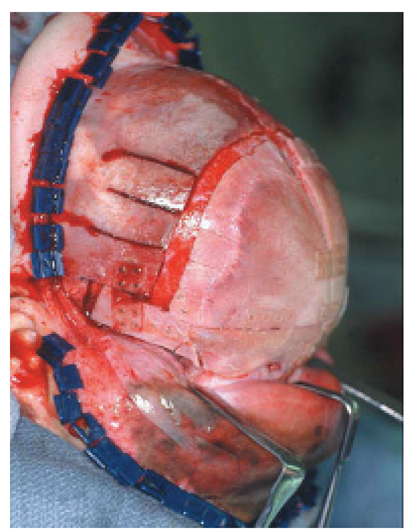


Figure 76.21 Superior view following fixation of bandeau but before placement of frontal segments.



(a)



(b)

Figure 76.22 (a) Barrel-staving bone cuts are manipulated via bone benders and (b) final fixation achieved via resorbable plates.

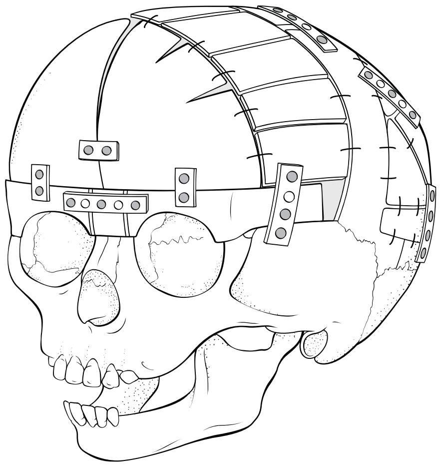
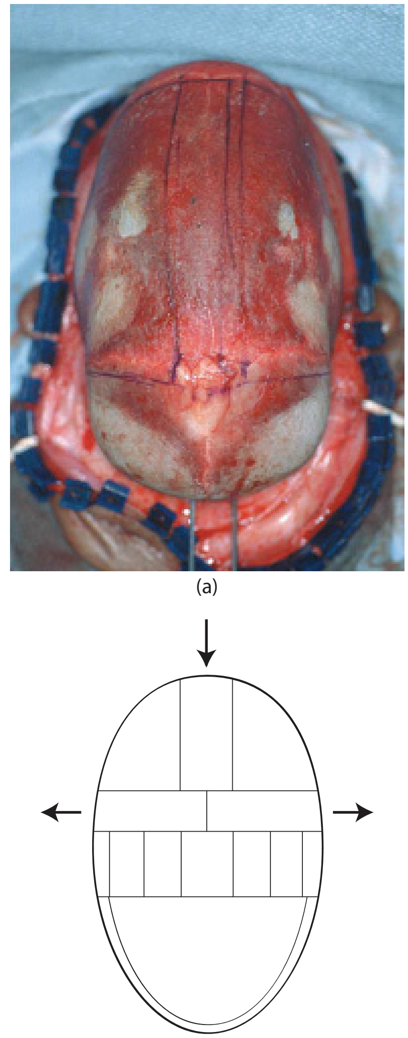


Figure 76.23 Total cranial vault reshaping and resorbable plate fixation to correct sagittal synostosis.

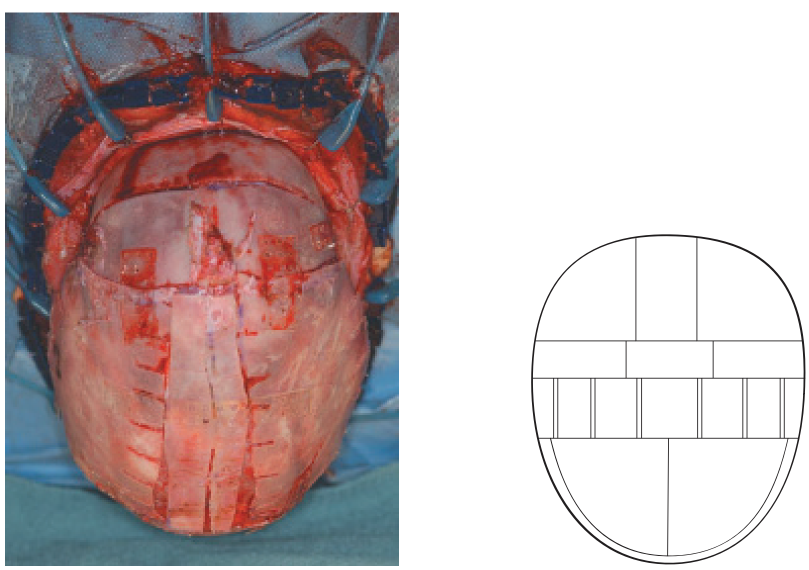


(a)

(b)

Figure 76.25 (a) Superior intraoperative and (b) schematic views before total cranial vault reshaping and fixation.

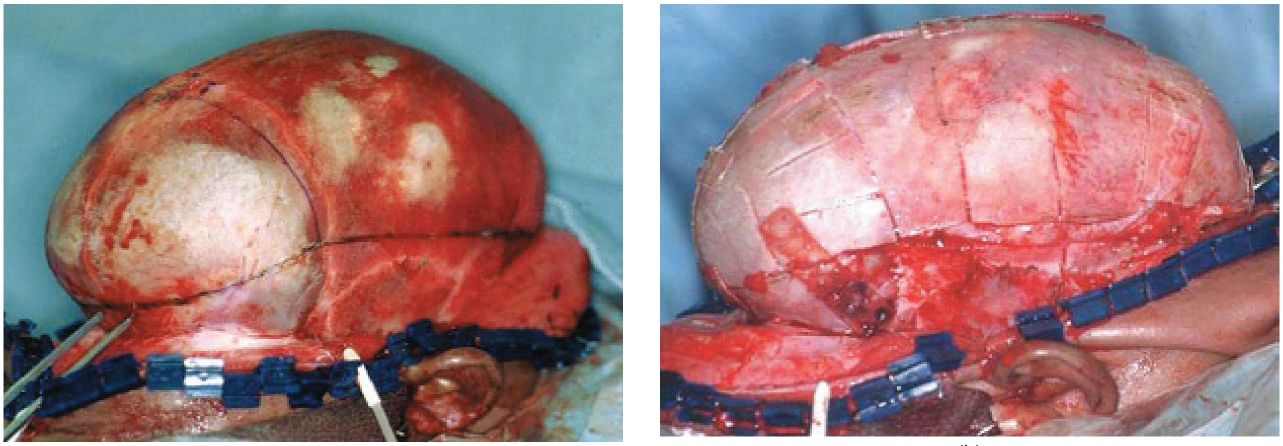
Figure 76.24 Prone positioning for total cranial vault reshaping.



(a)

(b)

Figure 76.26 (a) Superior intraoperative and (b) schematic views following total cranial vault reshaping and fixation.



(a) (b)

Figure 76.27 Lateral intraoperative views (a) before and (b) after total cranial vault reshaping.

- Intraoperative (Figure 76.26a) and schematic (Figure 76.26b) superior views after total cranial vault reshaping to increase the biparietal width and reduce the frontal and occipital projection.
- Intraoperative left lateral view before reshaping (Figure 76.27a) and after reshaping and fixation (Figure 76.27b).

COMPLICATIONS

Operative

- Excessive blood loss
- Subdural haematoma formation
- Cerebrospinal fluid loss
- Anaesthetic complications
- Periorbital injury
- Death

Early post-operative

- Bleeding
- Haematoma
- Corneal abrasion
- Stitch abscess
- Cerebrospinal fluid leak
- Volume and electrolyte disturbances
- Infection/meningitis
- Loss of vision
- Airway obstruction
- Death

Late post-operative

- Incisional alopecia
- Hypertrophic scarring
- Skull and orbital irregularities
- Diplopia, strabismus or canthal drift
- Sterile abscess secondary to plate hydrolysis

Top tips

- Elevation of a coronal flap should be in the subperiosteal plane with inclusion of the temporalis muscles maintaining attachment to the flap.
- Development of a supraorbital bandeau with a minimum height of 1.5 cm.
- Liberal placement of barrel-staving osteotomies to facilitate intraoperative three-dimensional changes and post-operative moulding if necessary.
- Use of resorbable plate fixation thereby avoiding the need for plate and screw removal or migration.

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77

Surgical management of orbital hypertelorism

DAVID M YATES, JENNIFER E WOERNER and G E GHALI

CONTENTS

HYPERTELORISM CORRECTION

Justification

Orbital hypertelorism is defined as an increased distance between both the medial and lateral sides of the orbits and should not be confused with telecanthus.[1–3] It is a physical finding associated with a number of congenital midline anomalies: craniofrontonasal dysplasia, frontonasal dysplasia, encephalocele, midline dermoid cyst, syndromes characteristic of midface retrusion and craniosynostosis (e.g. Apert and Crouzon syndromes), and atypical midline cleft anomalies. Though all patients with hypertelorism exhibit some telecanthus, not all patients with telecanthus are hyperteloric (Figures 77.1 and 77.2, Table 77.1).[2,4–6] These anomalies characteristically cause widening of the upper craniofacial segment and orbital hypertelorism.[7,8] Generally, these are non-progressive entities and best addressed once the cranio-orbital units are near skeletal maturity (5–8 years of age).[7,9] The extent and location of facial widening dictates which procedure is performed: box osteotomies versus facial bipartition.

PRE-OPERATIVE ASSESSMENT

- Contrast computed tomography (CT) with three-dimensional (3D) reconstruction with 1-mm cuts
  - Contrast is helpful in enhancing brain parenchyma and intervening soft tissues.
- Construction of a 3D model
  - In asymmetric cases, the use of virtual surgical planning is helpful.[1]
  - Determine surgical plan from using 3D model (Figures 77.3 and 77.4).
- Ancillary assessment[11]
  - Ophthalmology
    - Pre-operative and post-operative assessments.
- This population pre-operatively may exhibit epiblepharon, astigmatism and exotropia.
  - Genetics
  - Orthodontic
- Decision for box osteotomies versus facial bipartition

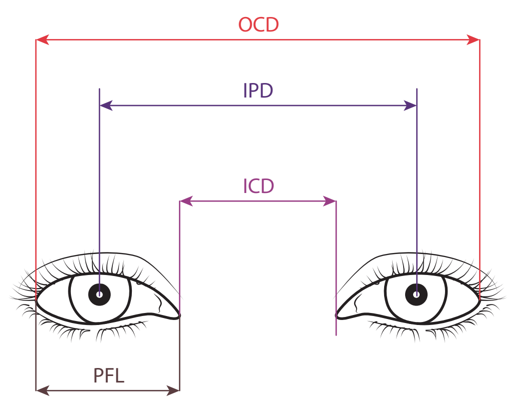

Figure 77.1 Some definitions pertaining to orbital measurements. ICD, inner canthal distance; IPD, inter pupillary distance; OCD, outer canthal distance; PFL, palpebral fissure length.

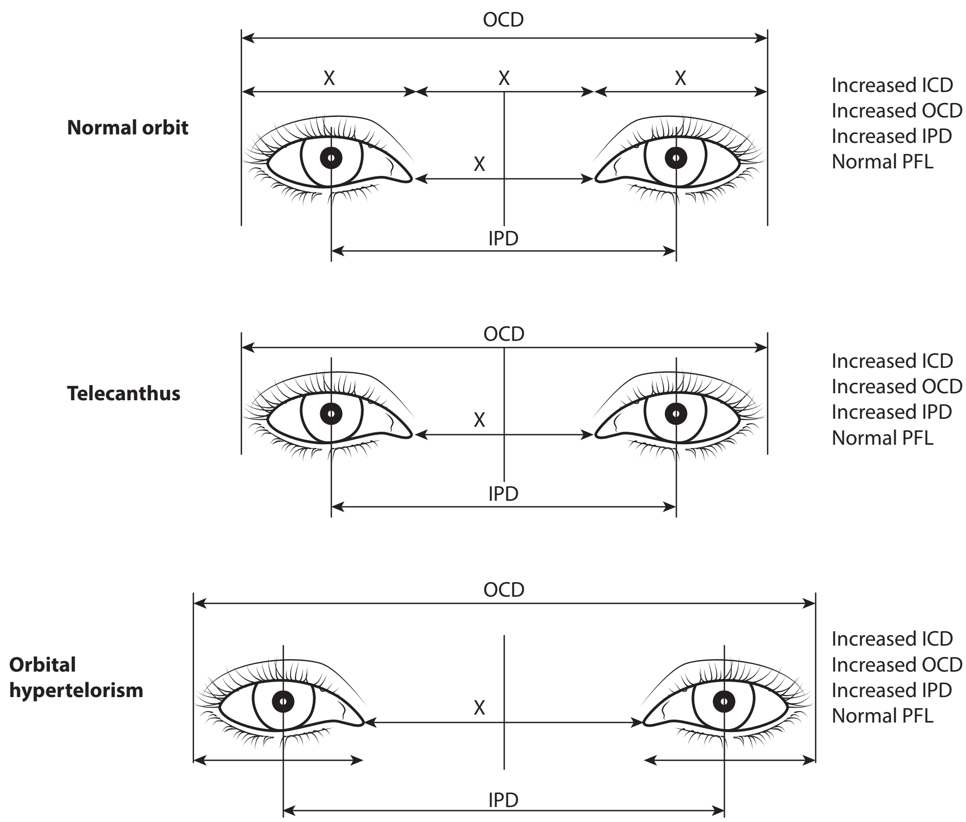

Figure 77.2 Graphic representation of various measurements as seen in normal orbit (upper row), in orbital telecanthus or pseudo-hypertelorism (middle row) and in orbital hypertelorism (lower row). ICD, inner canthal distance; IPD, inter pupillary distance; OCD, outer canthal distance; PFL, palpebral fissure length.

Table 77.1 Intercanthal distance

- Normal
  - At birth: 15 mm
  - At 12 years: 23 mm
  - Adults: 22–28-mm females and 24–32-mm males

Sources: Songur E et al., *J Craniofac Surg*, 1997; 8(1): 29–31; Whitaker LA and Vander Kolk C, *Otolaryngol Clin North Am*, 1988; 21(1): 199–214; Hansman CF, *Radiology*, 1966; 86(1): 87–96.

BOX OSTEOTOMIES

Indications

- Isolated orbital hypertelorism without maxillary constriction

Surgical goals[4]

- Medialize the two orbits to a more normal position.
- Correct any orbital dystopia.
- Narrow the nasal dorsum and reconstruct to create a nose with adequate projection.
- Correction of soft tissue excess or blemishes.

Figure 77.3 Proposed osteotomies for patient with hypertelorism.

Technique[6–8,10,11–14]

- Airway management
  - An oral RAE tube is placed and secured to the midline chin with a 0.0 silk suture.
  - Prepping.

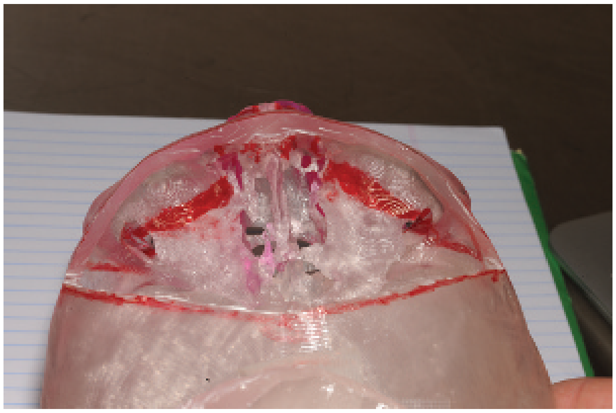

Figure 77.4 Bird's-eye view after frontal craniotomy and superior orbital roof osteotomies.

- Tarsorrhaphy sutures of 5.0 silk from grey line to grey line just lateral to the pupil of each eye.
- Mayfield headrest with shoulder roll.
- The coronal flap is outlined approximately 3 cm posterior to the hairline and is extended preauricularly as needed for exposure.
- A formal betadine or chlorhexidine prep is then performed.
- The patient is draped with full exposure of the head and neck down to the clavicles.

- Incision and dissection
  - Coronal incision
    - Subgaleal dissection ensues with an incision through the periosteum about 2 cm above the superior orbital rim. Once lateral to the temporal ridge, an incision down to the temporalis muscle is made through the superficial and deep layers of the temporalis fascia. The dissection is continued anteriorly and inferiorly in this layer to best preserve the facial nerve and superficial temporal fat pad. An incision along the back of the zygomatic arch through the layers may be performed for better access to the zygoma.
    - Extensive exposure of the nasal bones centrally with release of the supraorbital nerves, exposure of the lateral orbital rim and malar area, circumferential intra-orbital dissection to the posterior and middle third of the orbit (approximately 2 cm deep) and obliteration of the anterior and posterior ethmoidal arteries using bipolar electrocautery.
  - A large pericranial flap is harvested extending 2 cm posterior to the coronal incision and pedicled anteriorly and laterally.
    - Medial canthus: As long as anatomically feasible, the medial canthi should be left intact to better enable the moving of the soft tissues of the orbit.
    - Lateral canthus is usually dissected off from Whitnall's tubercle and reattached at the end of the surgery.
  - Maxillary vestibular incision (additional access – not generally required but occasionally helpful)
    - Standard Le Fort I maxillary vestibular incision made from premolar to premolar with extensive superior subperiosteal dissection to the inferior orbital rims bilaterally.
- Osteotomies (Figures 77.5 and 77.6)
  - Bifrontal craniotomy
    - A frontal bone flap is designed to leave 20 mm superior to the superior orbital rim – this will allow room for a bandeau and the supraorbital osteotomy.
- Craniotomy is then performed, and the dura is carefully dissected from the osteotomized bone.

Figure 77.5 Markings for the orbital box osteotomy on a skull model. The frontal craniotomy and the various markings for the cuts in the orbital walls and roof are shown in upper row and the left picture in lower row. The picture on right in lower row shows the moved orbits after removal of central excess tissue and completion of box osteotomy cuts. (Courtesy of Dr Mukund Jagannathan.)

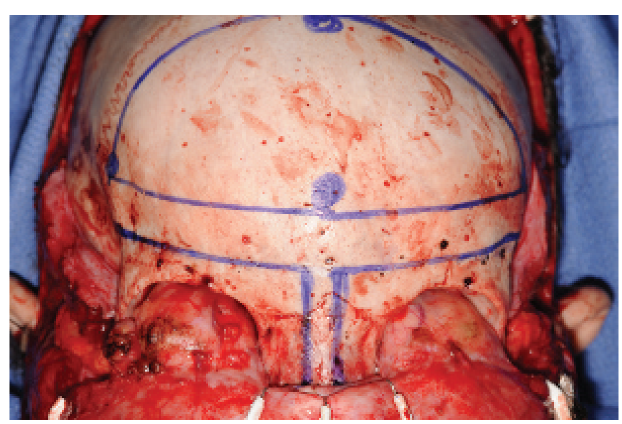

Figure 77.6 Proposed osteotomy in vivo (see Figure 77.3).

- Careful epidural dissection is performed around the anterior cranial fossa over the lateral aspects of the cribriform plate.
- Nasal mucosa is dissected under the nasal bones before the nasal osteotomy.
    - Lateral osteotomies (Figure 77.7)
        - Zygomatic arch is divided at the junction of the malar eminence.
- Lateral orbital osteotomy.
    - The entire lateral segment osteotomy is performed at least 2 cm posterior to the orbital rim – it is started at the inferior orbital fissure and carried superiorly.
    - Superior osteotomies (Figure 77.8)
        - Supraorbital osteotomy
        - 10 mm below and parallel to the inferior portion of the frontal craniotomy along the supraorbital rim – making sure to leave at least 6 mm of plateable bone intact at the supraorbital rim (frontal bar).
- Superior orbital roof osteotomy
    - The cut is made through the orbital roof staying at least 2 cm from the supraorbital margin; the osteotomy should stop short of the cribriform plate to protect the olfactory nerves.[4] It is carried laterally through the sphenoid wing.
- Medial osteotomies
    - Medial resection
        - Abnormally shaped nasal dorsum
            - Generally, a V- or U-shaped flap is usually performed.
            - Midline resection of the nasal septal complex with preservation of the mucosa.
        - Usable nasal dorsum (Figures 77.9 and 77.10)
            - Paramedian bony resection is performed.
            - May preserve septum and resected bone (for grafting).
        - 6 mm of bone is preserved around the orbit in all directions to enable appropriate fixation to be placed.
- Medial orbital osteotomy
    - Using a thin chisel, identify and preserve the nasolacrimal duct system with a nerve hook. The osteotomy is carried posterior to the lacrimal crest in order to adequately protect the nasolacrimal duct system. This osteotomy is then connected to the inferior orbital fissure.

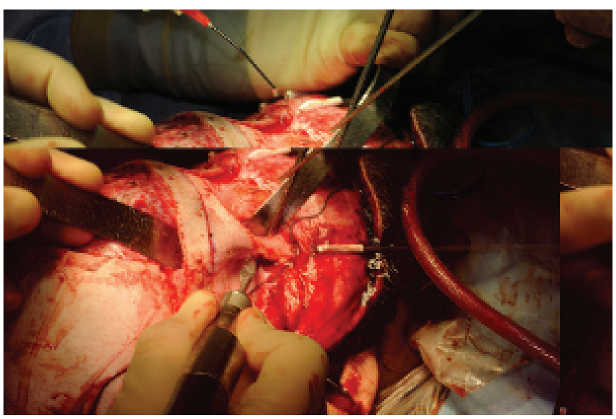

Figure 77.7 Lateral osteotomy.

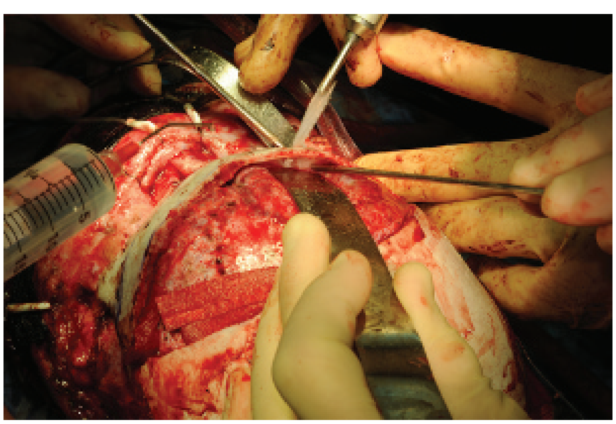

Figure 77.8 Supraorbital osteotomy.

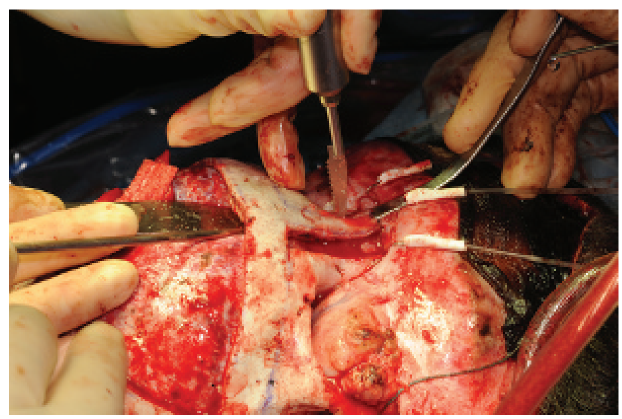

Figure 77.9 Lateral view of paramedian osteotomy.

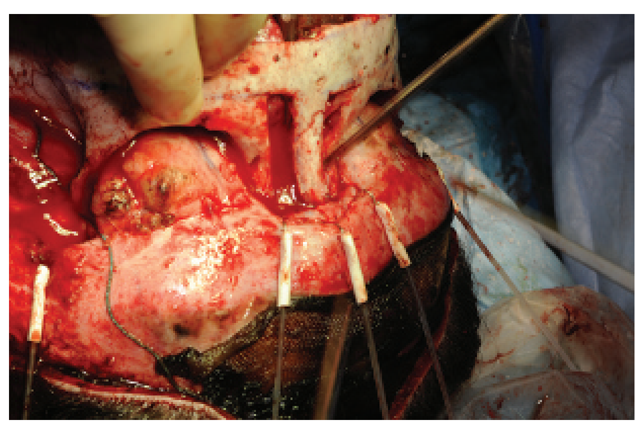

Figure 77.10 Frontal view of paramedian osteotomy.

- Double action rongeurs are used to remove hyperplastic ethmoidal air cells. Preservation of the cribriform plate with bilateral removal of the ethmoids along the length of the medial orbital roof osteotomy[15,16] (Figure 77.11).
- Separation of the bony nasal septum from cranial base (not necessary if midline is purposely being preserved).
- Performed using a thin straight chisel just anterior to the crista galli and aiming at the posterior portion of the hard palate (Figure 77.12).
- Inferior osteotomies
  - Infra-orbital osteotomy (Figure 77.13) May be placed above or below the infraorbital nerve, attention should be paid to the anatomic position of unerupted tooth buds. (May be performed through the coronal flap or through a maxillary vestibular incision.)
- Inferior orbital floor osteotomy (Figure 77.14)
  - Via the coronal flap connecting the medial intra-orbital osteotomy to the inferior orbital fissure using a thin osteotome.
- Mobilization (Figure 77.15)
  - Use osteotomes to ensure complete osteotomies and to mobilize.
  - Only a minimal step-off at the medial orbital wall is tolerated – if significant, the posterior medial portion of the orbit should be impacted.

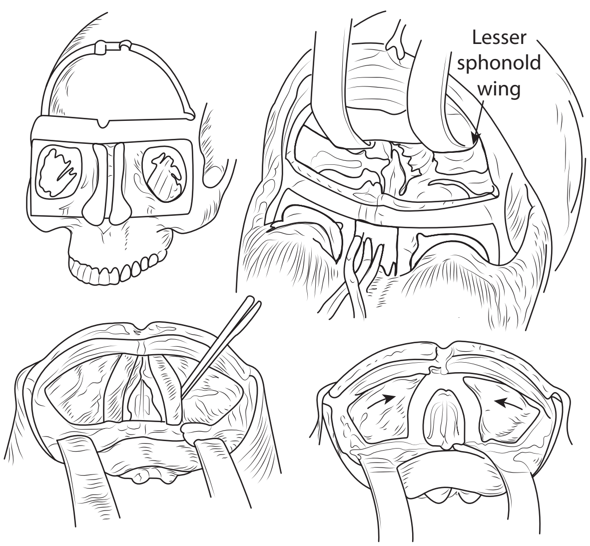

Figure 77.11 (a) Resection of a median segment from the anterior wall of the interorbital space. The ethmoid cells are exenterated. (b) Osteotomies of the anterior cranial vault with preservation of the cribriform plate. (c) Bone is resected anteriorly to the cribriform plate and also along each side to permit translocation without impinging on the olfactory nerves. (d) The shape of the segments of bone resected from the anterior cranial fossae varies, depending on the type of translocation of the orbits required to correct the deformity. (From Converse JG, *Reconstructive Plastic Surgery*, Saunders, Philadelphia, PA, 1977.)

- Fixation (Figures 77.16 and 77.17)
  - The decision to use resorbable versus titanium hardware is based on the age and bony development of the patient.
  - Hardware placed in glabellar area to secure the two segments to each other.
  - Advancement at the zygoma is measured with caliper to ensure symmetry and fixation is placed.

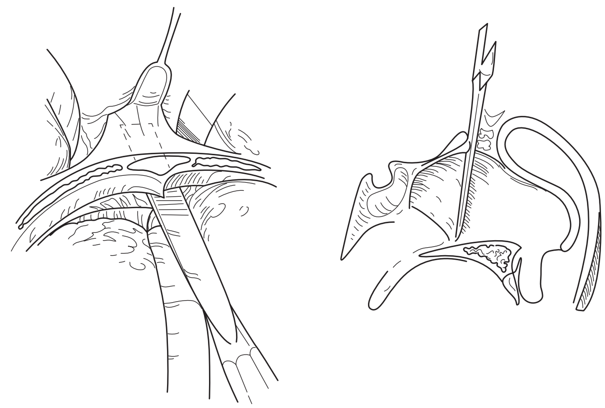

Figure 77.12 Separation at bony nasal septum from cranial base.

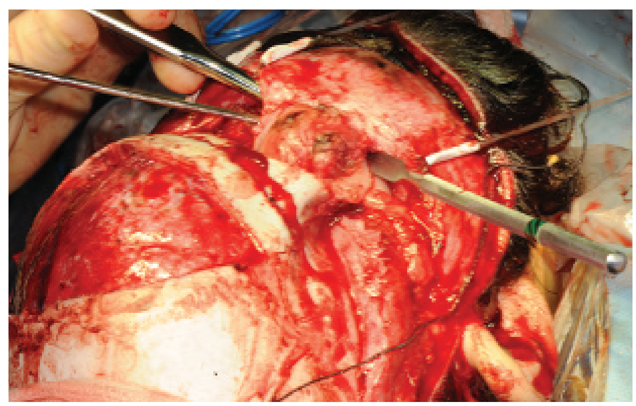

Figure 77.13 Infraorbital osteotomy.

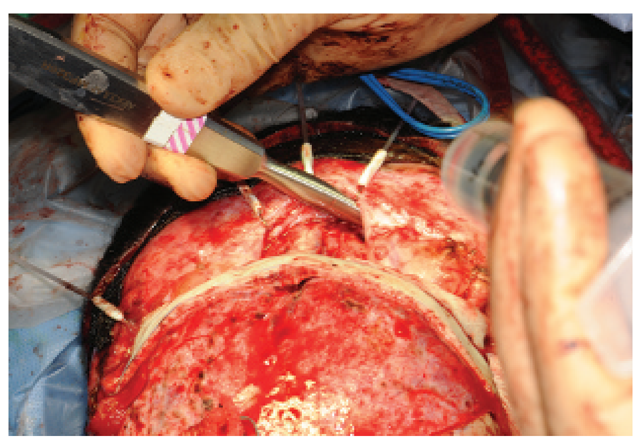

Figure 77.14 Inferior orbital floor osteotomy.

- Bone grafts
  - Nose
    - If medial excision of bone is performed – the dorsum should be reconstructed with a parietal cranial bone graft.
    - When a bifid tip is present an open rhinoplasty approach is used to access the tip and approximate the lower lateral cartilages over the cranial bone graft.

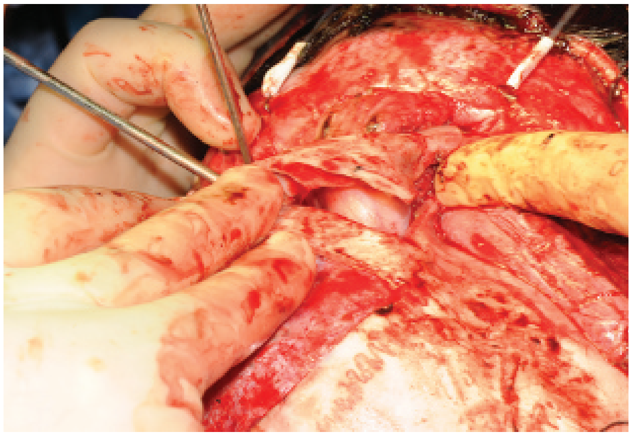

Figure 77.15 Mobilization of ostotomies.

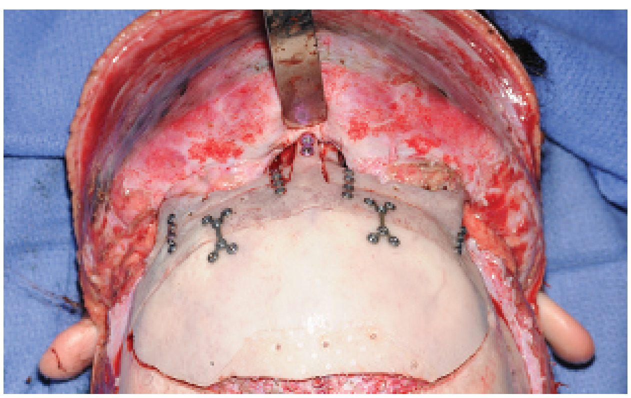

Figure 77.16 Bird's-eye view of fixation.

Figure 77.17 Profile view of fixation.

  - Lateral osteotomy sites
    - Cranial bone grafts are also placed at the lateral osteotomy sites in order to stabilize the medialization of the orbital boxes.
- Additional procedures (often necessitated)
  - Medial canthopexy (if needed)
    - A 24-gauge stainless steel wire secured to drill holes is placed in the contralateral nasofrontal junction.
  - Lateral canthopexy
    - A 24-gauge stainless steel wire is secured to two holes that are placed at the new frontozygomatic suture.
  - Pericranial flap
    - Occasionally needed in the extradural space created by the obliteration of the ethmoids/nasal septum. Helps to inhibit ascending infection and eliminate dead space.
    - If the frontal sinus has formed (usually by the age of 7), a proper frontonasal duct obliteration and sinus cranialization is performed.
  - Medial skin resection or rearrangement
    - Occasionally used if significant redundant skin is present.
      - Recommend midline incision from tip of nose to glabella.
    - Excess soft tissue may be stented using fibrin glue, augmented with transnasal stiches and a bolster (Figure 77.18).
    - V-Y advancement or a Z-plasty may be used to lengthen the nose when indicated.[14]
- Closure
  - Suspension of the temporalis muscle anteriorly to the lateral rims – drill holes and use polydioxone (PDS) suture.

Figure 77.18 Completion of procedure.

- Place Jackson–Pratt Suction drains bilaterally and secure externally with 2.0 silk suture.
- Close galea and subcutaneous suture with 3-0 vicryl.
- Staple skin closed.
- If intraoral incisions are present close with continuous interlocking 3.0 chromic gut suture.

Post-operative care[17]

- Immediate post-op CT scan with contrast
- 8-hour post-op CT scan with contrast
- Placement of nasal trumpets for 3–5 days
  - Limits pressure gradient at anterior cranial base
  - Allows re-epithelialization of nasal mucosa
- A 10-day course of intravenous antibiotics

FACIAL BIPARTITION[8] (FIGURE 77.19)

Indications[9]

- Conditions which result in transverse dental arch narrowing/restriction with medial upward cant in addition to hypertelorism (Figure 77.20).
  - Craniofacial dysostosis syndromes such as Apert and Crouzon.
  - Also indicated for some craniofrontonasal dysplasia and atypical midline cleft anomalies.

Surgical goals[4]

- Medialize the two orbits to a normal position and lateralize the dentition.
- Correct any orbital dystopia.
- Narrow the nasal dorsum, and reconstruct to create a nose with adequate projection.
- Correction of soft tissue excess or blemishes.
- Widen maxilla (Figure 77.20).

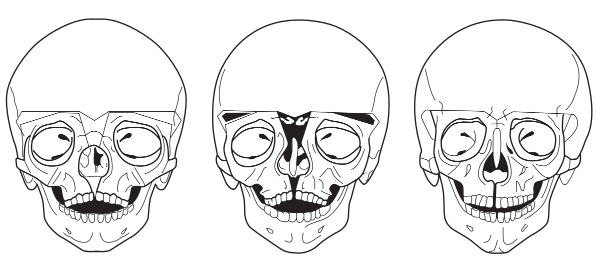

Figure 77.19 Facial bipartition surgical technique. (Left) Osteotomy sites of the hemifacial segments to be rotated with the medial bony triangle to be excised. (Center) Direction of the rotation of the hemifacial segments towards the midline. (Right) Final result after shifting the hemifacial segment and osteofixation. Cranial bone graft to the nose can be performed at the same surgical procedure.

Technique[4,6–9,13,18,19] (Figure 77.21)

- Airway management
  - An oral RAE tube is placed and secured similar to that described in section 'Box Osteotomies: Technique'.
  - Prepping.
  - Basic prep as in box osteotomy technique with the following additions:
    - A throat pack is placed and a 2-minute peridex rinse is performed.
    - Erich arch bars are placed on the maxillary teeth.
- Incision and dissection
  - Coronal incision and dissection similar to that described in section 'Box Osteotomies: Technique'.
  - Maxillary vestibular incision (Figure 77.23a).

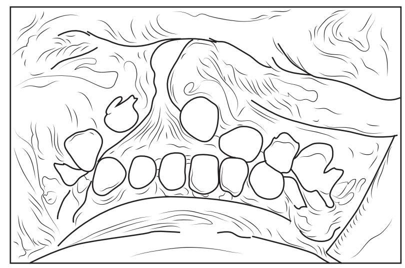

Figure 77.20 Intraoral diagram of maxillary cleft.

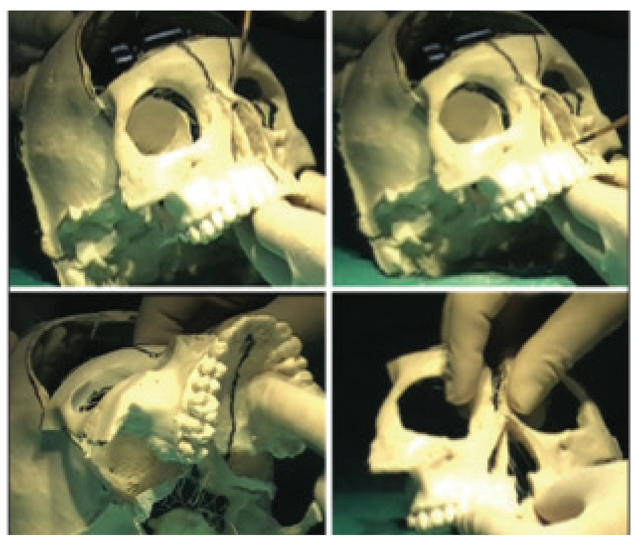

Figure 77.21 Markings for the facial bipartition. On a skull model. The upper row shows that the frontal craniotomy has been performed and the cuts in the orbital roof, lateral wall and the floor have been made. The zygomatic arch has been divided and the pterygomaxillary cut has also been completed. Upper row left shows markings for the removal of the central bony excess. The picture in upper row right and lower row left shows the markings for splitting the palate in midline. The picture in lower row on right shows completion of cuts and medializing the two halves of the facial bipartition. (Courtesy of Dr Mukund Jagannathan.)

- Osteotomies (Figure 77.22)
  - Bifrontal craniotomy
    - In contrast to that in section 'Box Osteotomies', no frontal bar is preserved in order to allow unfettered rotation of the hemifacial segments.
      - Craniotomy and epidural dissection is then performed similar to that described in section 'Box Osteotomies: Technique'.
  - Lateral osteotomies
    - Similar to that described in section 'Box Osteotomies: Technique' with the only variation being the extension of the lateral orbital osteotomy into the lateral Tenon extension.
  - Superior osteotomies
    - Superior orbital roof osteotomy is similar to that described in section 'Box Osteotomies: Technique'.
  - Medial resection
    - The medial resection and medial orbital osteotomy is identical to that described in section 'Box Osteotomies'.
  - Pterygomaxillary osteotomy (intraoral or coronal approach)
    - Intraoral approach
      - Using pterygoid osteotomes separate the maxilla from the pterygoid plates.
      - Requires a more extensive maxillary dissection.
    - Coronal approach
      - Pass an osteotome from the inferior orbital fissure down through the pterygomaxillary junction.
      - One hand is placed intraorally while the other holding onto the osteotome – a mallet is then used to advance the osteotome.
      - Confirmation of osteotomy is performed with spreaders.

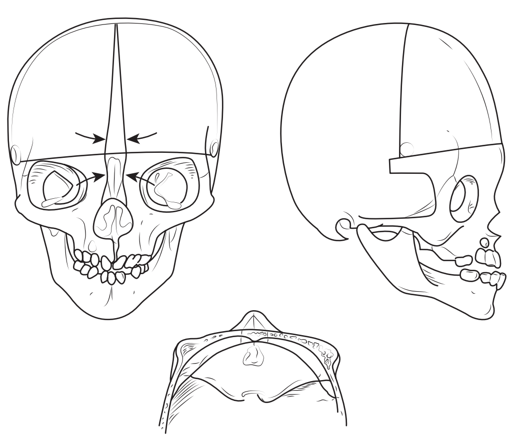

Figure 77.22 Overview of proposed facial bipartition osteotomies.

- Mobilization
  - Rowe forceps and Seldins are simultaneously used to achieve a controlled disimpaction of the two halves of the face, which are then rotated to the midline.
  - Due to rotation after mobilization, triangular-shaped wedges are removed from the lateral orbital rims for a more appropriate fit against the frontal bone.
- Maxillary segmentation (Figure 77.23)
  - Maxillary vestibular incision
    - Standard maxillary vestibular incision made from canine to canine with complete subperiosteal dissection of nasal floor and a subperichondrial dissection of the inferior portion of the septum.
  - Osteotomy (Figure 77.24)
    - Septum is separated from the maxillary crest using a nasal-septal osteotome.
    - Sagittal osteotomy of the maxilla in the midline using initially a reciprocating saw then a small spatula osteotome for completion.
    - Bone is removed as needed.
  - Closure of oral mucosal wound using 3.0 vicryl in a watertight manner
  - Maxillary splint placement
    - The maxilla is wired into a splint fabricated pre-operatively from an impressions and model surgery which have placed the maxilla in the proper transverse relations with the mandible.
- Fixation (Figure 77.25)
  - The fixation is similar to that described in section 'Box Osteotomies'.
- Bone grafts
  - The bone grafts utilized are similar to that described in section 'Box Osteotomies'.
- Separation of anterior cranial fossa from sinuses
  - A large sheet of gel foam is placed over the superior remnant of ethmoid air cells. Tisseel is then placed sealing off the sinuses. The harvested pericranial flap may then be placed in the defect.
- Anterior cranial vault
  - The bones are reshaped and advanced as needed and fixed to the superior orbital rims.
- Additional procedures (often necessitated)
  - Described under section 'Box Osteotomies.'
- Closure
  - Closure is similar to that described in section 'Box Osteotomies'.

Post-operative care[17]

The post-operative care is similar to that described in section 'Box Osteotomies' (Table 77.2).

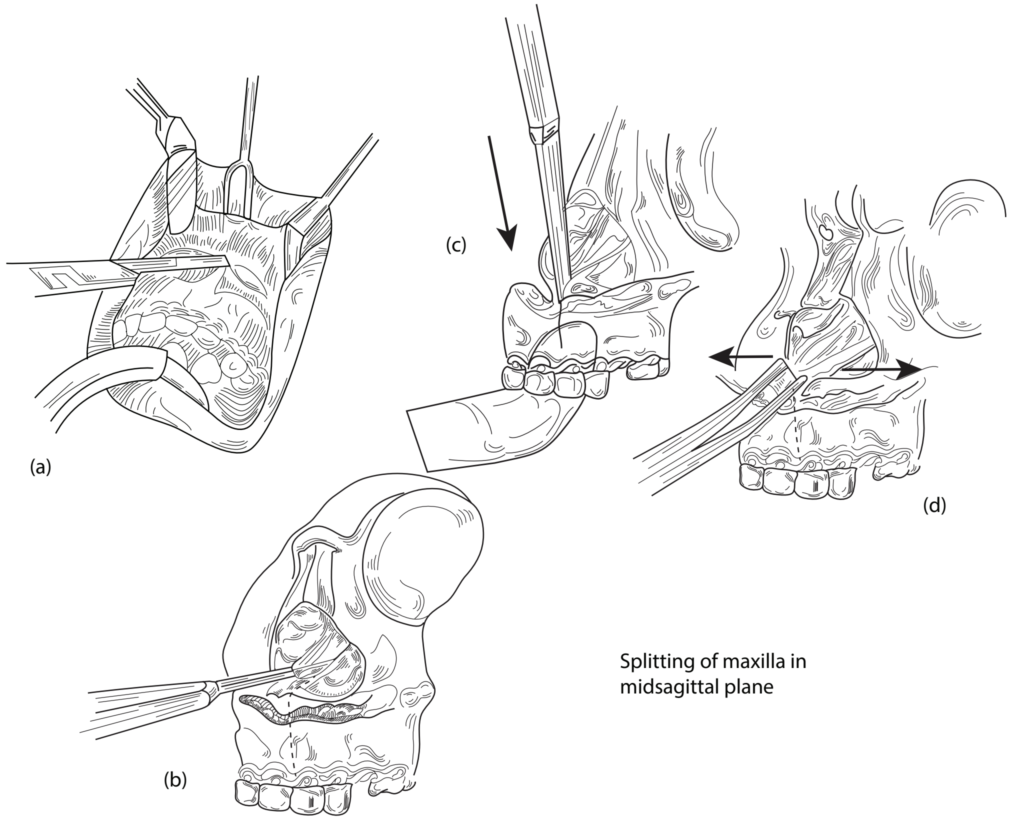

Figure 77.23 Sagittal osteotomy of the maxilla as used in the bipartition procedure. (a) Small midline vestibular incision with exposure of the piriform rim, nasal floor and septum. (b) Nasal-septal osteotome used for separation of the septum along the maxillary crest. (c and d) A straight osteotome is then used to complete the segmentalization, and small bone spreaders confirm mobility of the two maxillary halves. (From Posnick JC, Craniofacial dysostosis syndromes: A staged reconstructive approach, In: Turvey TA, Vig KWL, Fonseca RJ, editors, *Facial Clefts and Craniosynostosis: Principles and Management*, W.B. Saunders, Philadelphia, PA, 1995. With permission.)

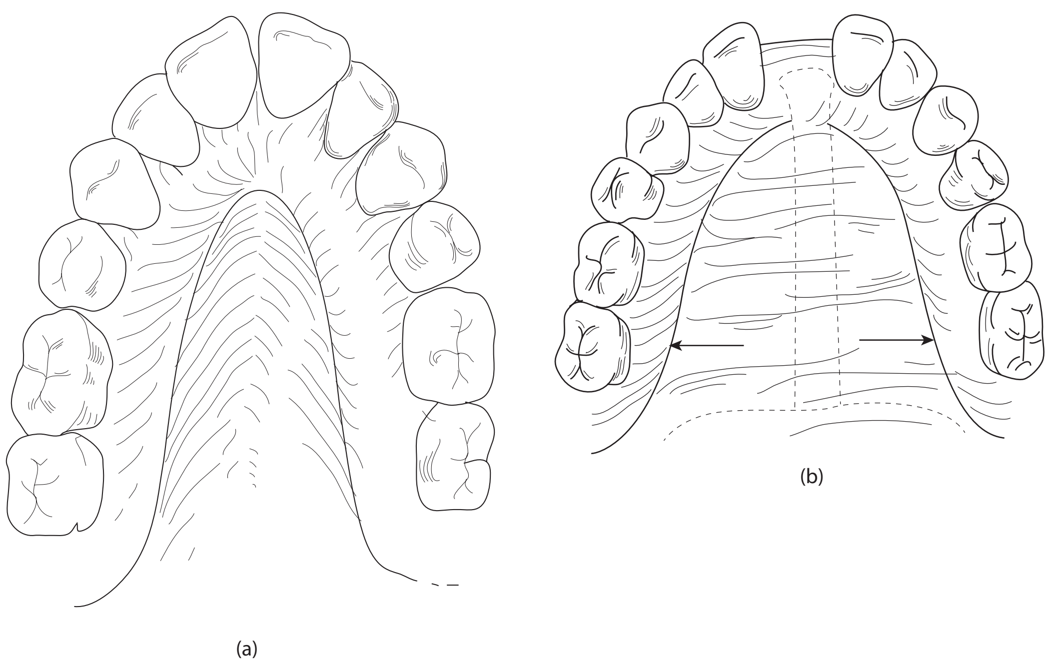

Figure 77.24 (a) High arched palate and narrowed maxillary arch width are common findings in children with craniofacial dysostosis syndromes and craniofrontonasal dysplasia. (b) During the facial bipartition, upper facial movements towards the midline result in lateral expansion of the maxillary arch form. Resistance is encountered from palatal soft tissues at this location.

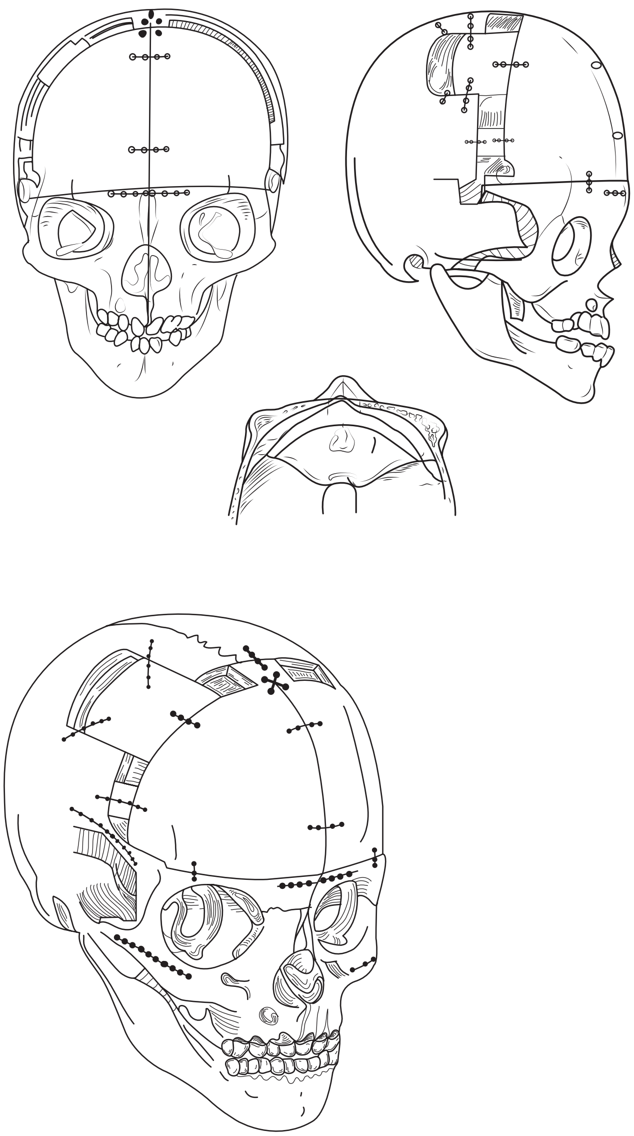

Figure 77.25 Fixation for facial bipartition.

REVISION RATE FOR ORBITAL HYPERTELORISM SURGERY 76%[8,12]

- 24%–25% underwent some type of bony revision
- 52% underwent some type of soft-tissue revision
    - Medial/lateral canthopexy
    - Central soft-tissue revision
- 24%–36% did not need any revision
- Nasal revision
    - Medial excision followed by bone grafting of the dorsum commonly produces restricted nasal growth, therefore a nasal revision with secondary bone grafting should be expected.
    - If anatomy permits, the septum and dorsum should be preserved during the first surgery – in most cases this is not possible.

Table 77.2 Complications

- Mortality: 0%–2%
- Cerebrospinal fluid (CSF) leak: 0%–10%
- Subdural haematoma: 1%
- Epidural haematoma: 1%
- Infection: 1%–10%
- Permanent V2 sensory loss
- Hyposmia: 21%[14]
- Ophthalmologic
    - Post-operative enophthalmia
        - An increase in orbital volume occurs secondary to the resection of the ethmoids and the anterior rotation of the lateral orbital walls[7]
    - Exotropia: Common immediately post-op but usually self corrects
    - Esotropia: Likely related to a bowing of the medial rectus muscle across the medial osteotomy site[15]
    - The need for additional strabismus surgery is common in this patient population

Sources: Marchac D et al., *Plast Reconstr Surg*. 2012; 129(3): 713–727; Whitaker LA and Vander Kolk C, *Otolaryngol Clin North Am*. 1988; 21(1): 199–214; McCarthy JG et al., *Plast Reconstr Surg*. 1990; 86(2): 214–125; Ortiz Monasterio F et al., *Plast Reconstr Surg*. 1990; 86(4): 650–657.

PRIMARY REASONS FOR FAILURE/RELAPSE[7]

1. Technical failure at appropriately reducing anterior interorbital distance during surgery.
2. Relapse due to failure of the bone segments to remain stable (secondary to young age of surgical intervention or inadequate bone grafting at osteotomy sites).

Top tips

- Operation should not be considered before the age of 5 years.
- Transverse osteotomy below the orbits is made high to avoid tooth buds.
- Complete mobilization of the orbits or hemifacial segments must be achieved.
- Adequate fixation with bone grafting prevents relapse.

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78

Hemifacial microsomia

JANICE S LEE

CONTENTS

INTRODUCTION

Hemifacial microsomia is the second most common congenital anomaly of the craniofacial region. Abnormal development of the structures derived from the first and second branchial arches results in unilateral hypoplasia and asymmetry of the orbit, mandible, ear, cranial nerve VII and overlying soft tissue. Extracranial anomalies may occur. The characteristic finding of hemifacial microsomia, including bilateral involvement, is the asymmetry in craniofacial development.

Treatment is determined by the age of the patient (potential for growth) and the severity of the facial deformity affected by the mandibular type. The patient's psychosocial development should be considered in the timing of the surgical treatment. The timing of treatment remains controversial and influenced by the theories surrounding progressive or stable asymmetry.

Using the Pruzansky classification with the Kaban modification, most surgeons agree that the mandible types I and IIa may be treated with conventional orthognathic surgery or distraction osteogenesis. The mandible types IIb and III typically require reconstruction of the missing or deficient glenoid fossa-condyle-ramus (GCR) unit using costochondral grafts. Reconstruction of the affected ear often occurs between 6 and 9 years of age when the child is of adequate size to harvest an adequate amount of costochondral cartilage. The soft-tissue augmentation is typically carried out after skeletal construction. Augmentation can be achieved with microvascular free-tissue transfers, most commonly the scapular free flap, or fat injections, as we have noted with excellent aesthetic results. This chapter will describe the comprehensive work-up and the craniofacial surgical skeletal treatment after growth is complete for the type IIb or III mandible in a patient who has completed pre-surgical orthodontic preparation.

EXAMINATION OF THE PATIENT

Many patients tend to posture the head towards the affected side or may have musculoskeletal restrictions. In such cases, the patient should be examined in resting and corrected position with the horizontal facial plane established (Figure 78.1). Skin markings may help establish the facial planes. The extent of the facial asymmetry should be documented and diagnostic photographs should be obtained.

Assessment should include the following:

- Facial animation, smiling and facial nerve function
- Occlusal cant (a tongue blade may be helpful) and position of dental midlines
- Profile view from left and right (Figure 78.2)
- Temporomandibular joint examination (deviation with opening, any symptoms and range of motion, although it is not often limited)
- Masticatory muscles presence and function
- Degree of microtia
- Soft-tissue deficiency
- Submental view (Figure 78.3)
- Intraoral examination, including the overjet and overbite relationship, the amount of oral opening, the presence of a lateral shift or centric relation-centric occlusion (CRCO) discrepancy that is often seen in hemi facial microsomia (HFM) patients, and the movement of the soft palate.

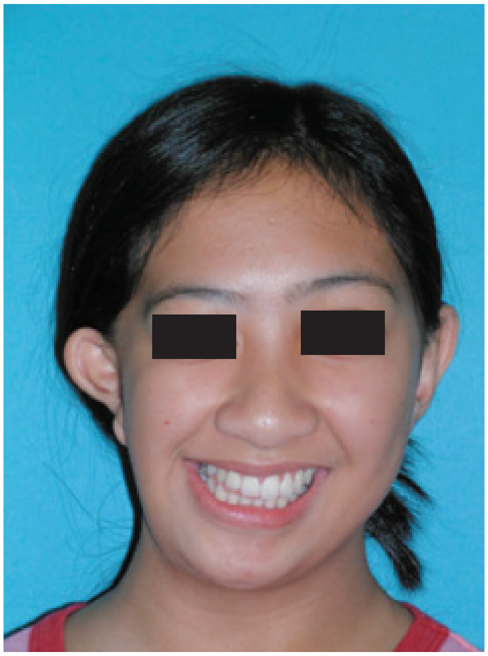

Figure 78.1 Pre-operative frontal smiling view with patient in corrected head position. The mandible and chin point are deviated to the right and there is an obvious maxillary and mandibular cant and rotation. The facial nerve is intact.

Figure 78.2 Pre-operative right lateral view demonstrating right microtia, retrognathia and short posterior face height.

DIAGNOSTIC IMAGES

As well as the two-dimensional (2D) radiographs, panorex, lateral and posterior–anterior (PA) cephalograms,

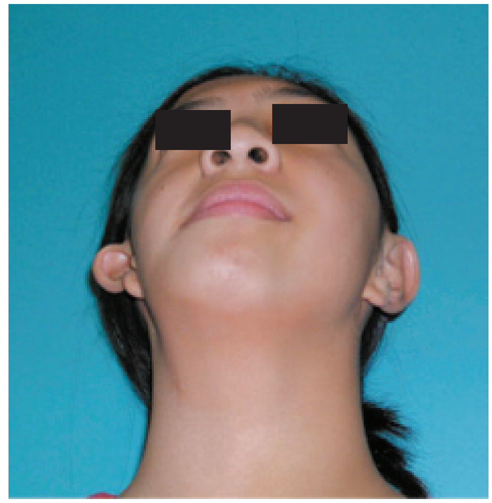

Figure 78.3 Pre-operative submental view demonstrating the extreme rotation of the chin point and deficiency of the right facial soft tissues.

Figure 78.4 Pre-operative 3D reformatted computed tomography (CT) showing the frontal view of a patient with left dominant hemifacial microsomia and type IIb mandible. From the 3D images, it is clear that hemifacial microsomia is not a unilateral condition but a condition that ultimately affects growth bilaterally.

three-dimensional (3D) images such as a spiral or cone-beam computed tomography (CT) with 3D reformatting prior to surgery helps to appreciate the skeletal deformity in all planes (Figures 78.4 and 78.5). The 3D images have demonstrated skull base asymmetry and the extreme rotation of the maxilla and mandible. The 3D CT allows for the fabrication of anatomical models that may be incorporated into the model surgery.

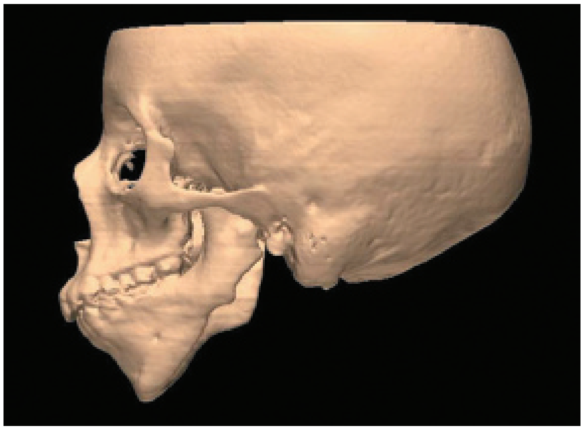

Figure 78.5 Pre-operative 3D reformatted CT of the lateral view of the same patient as in Figure 78.4.

MODEL SURGERY

Advanced technology is allowing for surgical treatment planning using virtual surgery software. This chapter will describe the more conventional treatment planning method.

Ideally, two anatomical models are requested for each surgical patient. One anatomical model is marked at all the midline structures whilst the second model is used to compare the baseline asymmetry. Using the orbital rims for the horizontal facial plane or an arbitrary horizontal facial plane if there is orbital dystopia, the projected facial midline is established by bisecting the horizontal plane with a perpendicular line. The foramen magnum or sella in the skull base may provide a reasonable midline structure in the submental view of the skull. The mandible and maxilla are then disarticulated from the skull base. For an ideal aesthetic result, particularly in profile, the steep occlusal and mandibular planes need to be corrected, often with the fulcrum in the anterior maxilla on the unaffected side. The affected side often requires even further lengthening to correct the cant, thus, the surgical movements on the affected side become greater than 10 mm in most cases. The maxilla is often advanced and rotated to the facial midline (Figure 78.6). The mandible is then positioned to the maxilla. The muscle attachments and structures, such as the inferior alveolar neurovascular bundle, may limit the ease of moving the mandible into an ideal position. If necessary, the unaffected side is shortened.

Conventional model surgery is then performed on plaster models of the patient mounted in a semi-adjustable articulator.

The following points should be considered:

- Slight over-rotation of the maxilla (1–2 mm beyond the midline) is helpful.
- The intermediate splint is often bulky and demonstrates the significant change in position of the maxilla.
- The final splint can be fabricated in a non-adjustable articulator with the models in ideal maximal intercuspal position and then opened 2 mm at the molars on the affected side in anticipation for costochondral graft settling and remodelling.
- The maxillary occlusal plane is obtained with the face-bow parallel to the projected horizontal facial plane without placing the ear rod in the external auditory canal on the affected side if it is abnormally positioned.
- It may take multiple attempts to establish the CR of the mandible due to the absence of the GCR unit.

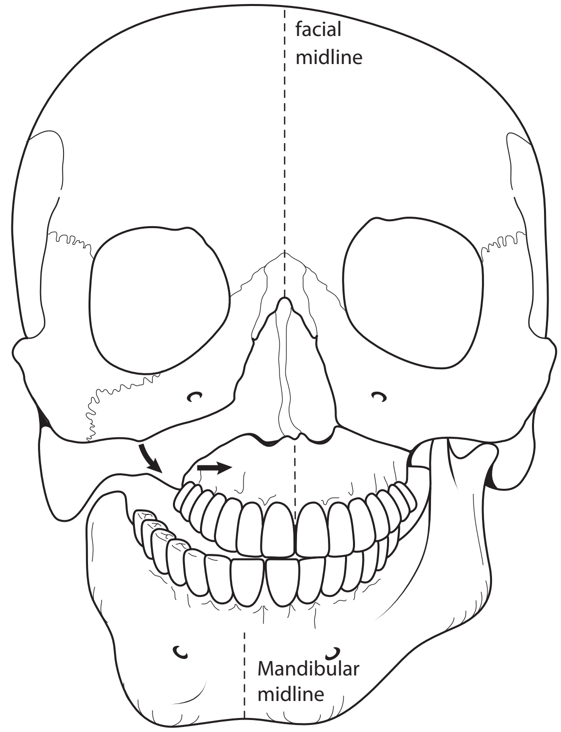

Figure 78.6 Model surgery on the anatomical model demonstrates the significant changes in the position of the maxilla and the expected rotation of the mandible in the intermediate phase.

SURGICAL MANAGEMENT

Once the patient is nasally intubated and positioned as if for an orthognathic procedure, a small area is shaved over the affected side to allow for a temporal extension of a preauricular incision (Figure 78.7). Pre-operative antibiotics, such as clindamycin and corticosteroids, such as dexamethasone, are provided. A shoulder roll is placed for extension of the neck with the head resting in a jelly doughnut. The patient is prepared and draped in the standard fashion for an orthognathic procedure. A sterile kirshner rod (k-rod) is placed between nasion and glabella to establish the pre-operative vertical position of the maxillary canines and central incisor and the alar base width. A throat pack is placed. Local anaesthetic, typically 1% lidocaine with 1:1,00,000 epinephrine, is injected along the unaffected ramus and in the maxillary vestibule. As with a two-jaw orthognathic surgical procedure, the unaffected

side sagittal split osteotomy is initiated but not completed (see Chapter 72).

Epinephrine-soaked neuropatties are placed in the incision site for haemostasis. Attention is then directed to the maxilla where a LeFort I osteotomy is performed (see Chapter 73). Mobilization of the maxilla with Rowe disimpaction forceps is critical. Both descending palatine arteries are routinely preserved. The intermediate splint is then secured between the mobile maxilla and the mandible by using 26 gauge wires. With the mandible carefully placed in centric relation, the maxilla is rigidly fixed using 2.0 plates at the piriform rims and buttresses (a total of four plates), starting with placement of the plates on the unaffected side (Figure 78.8). A laminar spreader is often used to stent down the maxilla on the affected side whilst the plates are placed. Measurements are taken from the k-rod to the canines and central incisor to confirm that the cant is corrected according to the planned movements. The sagittal split osteotomy is completed on the unaffected side and epinephrine-soaked neuropaddies are placed for haemostasis. Hypotensive anaesthesia is requested during the orthognathic procedures.

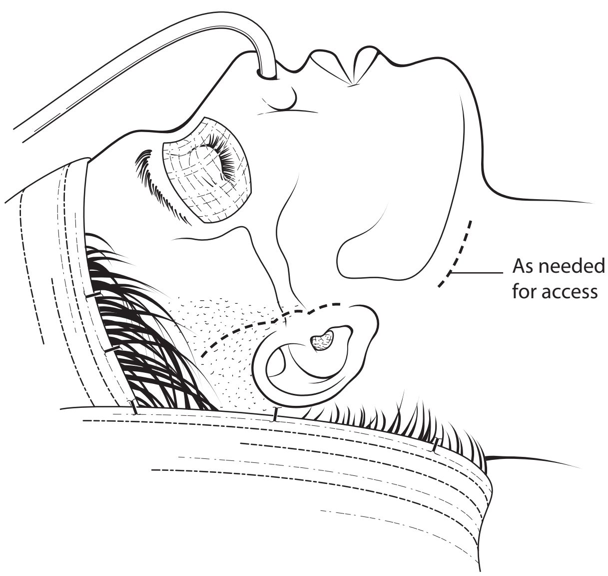

Figure 78.7 The skeletal structures and landmarks are identified and the preauricular incision with the temporal extension is mapped.

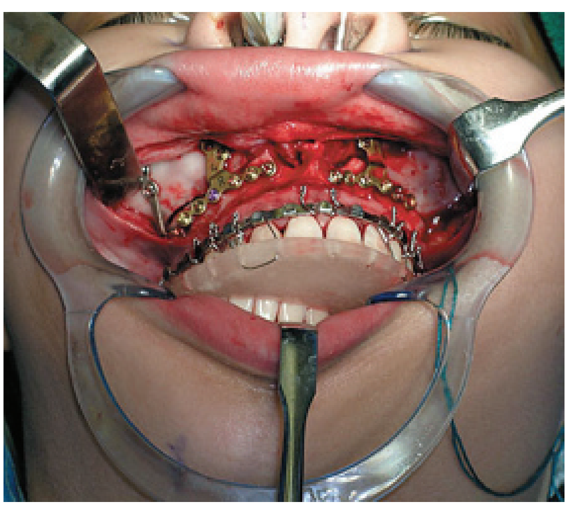

Figure 78.8 The maxilla is mobilized and rigidly fixed. Note the large intermediate splint and the intermediate position of the mandible.

EXTRAORAL APPROACH

Sterile preparation and draping of the patient is necessary for the extraoral approach to the remnant joint and ramus on the affected side and the harvesting of the costochondral bone grafts. The patient is positioned with the affected side exposed including the temporal, preauricular and submandibular incision sites. A soft roll is placed under the chest, preferably the contralateral chest to take advantage of the favourable anatomy of the rib. A sterile adhesive drape should be placed adjacent to the oral commissure to separate the oral cavity from the sterile field. Draping should be done such that access to the mouth is possible without contaminating the field. A two-team approach is ideal and efficient (see Chapter 19 and Chapter 63).

The preauricular incision is made anterior to the constructed ear and in the vicinity of the zygomatic root of the temporal bone. It is not unusual to find the reconstructed ear over the future site of the reconstructed condyle since the abnormal ear is often anterior and inferior in position. Care must be taken not to disrupt the soft tissue overlying the cartilage of the reconstructed ear. The site is anaesthetized with local anaesthetic. The preauricular incision extends to the constructed earlobe inferiorly and has a temporal extension that allows for greater anterior flap release and access to the temporalis myofascia if needed to line the reconstructed glenoid fossa. Despite the hypoplasia or agenesis of the local skeletal structures, there is some remnant of the anterior component of the temporalis muscle. Additionally, identifying the temporalis myofascial plane provides orientation, access to the zygomatic arch (if present) and allows for protection of the facial nerve if dissection is kept deep to this plane. Nerve stimulation is performed throughout the dissection to preserve the facial nerve. Once at the zygomatic arch, the dissection is carried out to the potential superior joint space. Medial dissection is kept minimal due to the potential vasculature that resides medially and due to the goal of positioning the reconstructed condyle laterally and posteriorly. A 2–3 cm submandibular incision is made approximately 2 cm below the rudimentary ramus and mandibular angle. This allows the incision to be below the final position of the angle and constructed ramus. Dissection is carried down to the affected mandible using nerve stimulation. Subperiosteal dissection is continued along the vestigial ramus to its most superior aspect. Muscle detachment, including the medial attachments, is necessary around the vestigial ramus to allow lengthening of the affected side. If

a remnant disc is present, it can be seen around the rudimentary condyle. It typically cannot be used. Blunt dissection is used to create a throughway from the mandible to the superior incision in the region of the zygomatic root where the glenoid fossa will be reconstructed. Gentle enlargement of this throughway is possible with blunt finger dissection to accommodate the costochondral graft. If there is an elongated coronoid process, it is resected through either incision. At this point, one person can access the oral cavity without contaminating the preauricular field and secure the final splint to the maxilla and place the patient in intermaxillary fixation (IMF) using 26 gauge wires.

The costochondral bone graft with a 3–5 mm cartilage cap, is positioned from the vestigial ramus to the superior joint space (Figure 78.9). A 6–7 cm costochondral graft is often required and positioned posteriorly and as far laterally as possible. A second 6–7 cm rib graft without a cartilage cap is cut into two shorter grafts; one graft is set aside for the maxilla and one is used to reconstruct the glenoid fossa and deficient or missing zygomatic arch, thus functioning as a posterior and lateral stop (Figure 78.10). This bone graft is secured to the deficient zygomatic arch or temporal bone with washers and 10–12 mm 2.0 screws. Prior to reconstructing the condyle, a temporalis myofascial flap is elevated and wrapped over the zygomatic arch and secured to the medial tissues with 4/0 interrupted vicryl sutures. This interpositional flap lines the newly reconstructed glenoid fossa and appears to prevent ankylosis of the joint. The costochondral bone graft is then secured to the native mandible (vestigial ramus) using three washers and 10–12 mm 2.0 screws (Figure 78.11). All sites are irrigated and a butterfly drain is placed in the area of the reconstructed condyle which exits in the submandibular region. The incisions are closed in layers with 4/0 vicryl with staples for the superficial layer of the scalp and 5/0 nylon for the superficial layer of the preauricular and submandibular incisions.

Attention is then turned to the oral cavity. The IMF is released and the mandible is gently opened and closed to determine the stability of the posterior/superior/lateral stop and mobility as a unit. Once confirmed, attention is then turned to the chin to complete the sliding genioplasty (see Chapter 72). The chin is often advanced, lengthened and rotated.

With the remaining rib graft, the lengthened maxilla on the affected side is stabilized with the interpositional bone graft. It is secured with a plate or sutured to one of the

Figure 78.10 The second rib graft is used as a lateral stop and augments the deficient zygomatic arch.

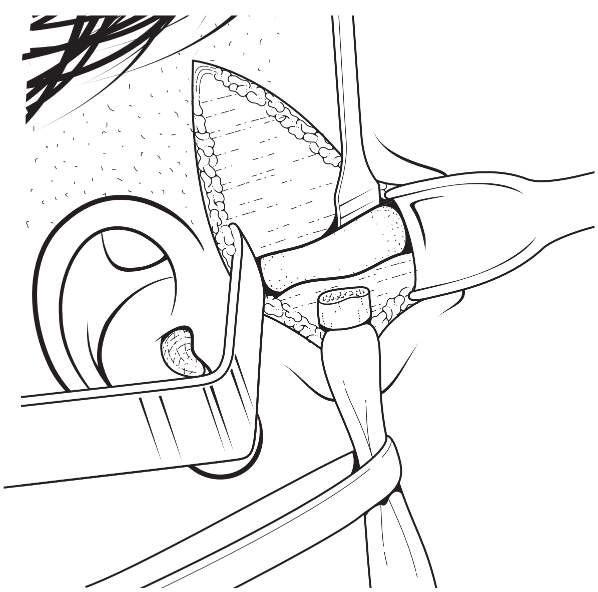

Figure 78.9 The costochondral graft is positioned superiorly and laterally.

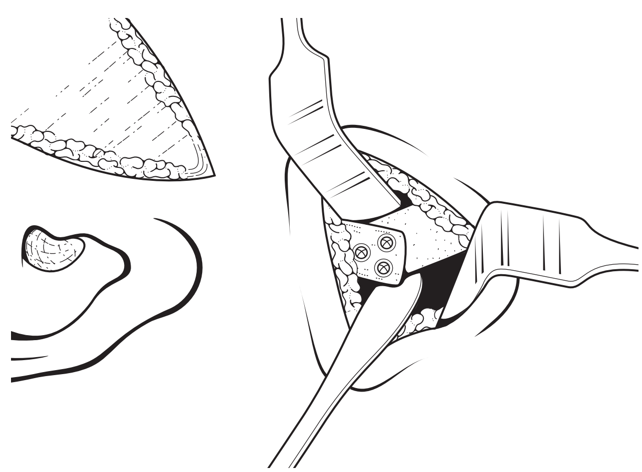

Figure 78.11 The costochondral graft is secured to the native mandible with screws and washers.

fixation plates. All intraoral sites are irrigated and closed with running 4/0 vicryl sutures. The patient is placed in IMF elastics for 3–4 weeks (Figure 78.12).

Post-operative points are as follows:

- Maintain guiding elastics once out of IMF for four more weeks with maxillary splint in place; encourage gentle opening exercise.
- Resume orthodontics once maxillary splint is removed (at 7–8 weeks after surgery).
- Soft-tissue augmentation after 6 months, may include free flap or fat injections.

Figure 78.12 Three years post-operative assessment demonstrating good facial symmetry and a stable occlusion. The patient had fat injections of the right face for soft-tissue augmentation 1 year after the skeletal surgery.

- Prior to soft-tissue augmentation and as patient's oedema decreases, soft-tissue asymmetry becomes marked, skeletal symmetry is stable.

Top tips

- Preparation and work-up of the hemifacial patient is the most critical step.
- Diagnostic imaging, particularly 3D imaging, and anatomic models are critical for treatment planning in patients with severe facial asymmetry.
- Basic orthognathic surgery principles apply.
- Anatomic limitations may restrict complete mobilization and ideal positioning of either the maxilla or mandible.

SUGGESTED READINGS

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79

Sleep apnoea and snoring, including non-surgical techniques

JOSEPH R DEATHERAGE and PETER D WAITE

CONTENTS

DEFINITION

Obstructive sleep apnoea syndrome refers to the condition of complete or partial airway obstruction during sleep which disrupts sleep architecture. It also results in excessive daytime somnolence (EDS).

Snoring is noisy breathing during sleep and represents partial airway obstruction. If loud enough, snoring can disrupt sleep architecture.

ETIOLOGY

Obesity-related cranio-maxillofacial syndrome, skeletal abnormalities, nasopharyngeal obstruction, macroglossia (Figure 79.1).

INDICATIONS FOR INTERVENTION

- Excessive daytime somnolence
- Respiratory distress index (RDI) > 20
- O_2 – desaturation >90% during sleep
- Hypertension
- Dysrhythmias

INDICATIONS FOR SURGICAL INTERVENTION

- Failure of non-surgical management
- Maxillofacial skeletal-anatomic airway abnormalities.

CONTRADICTIONS TO SURGERY

- Gross obesity
- Unstable cardiovascular disease
- Severe pulmonary disease
- Alcoholism or drug abuse
- Elderly

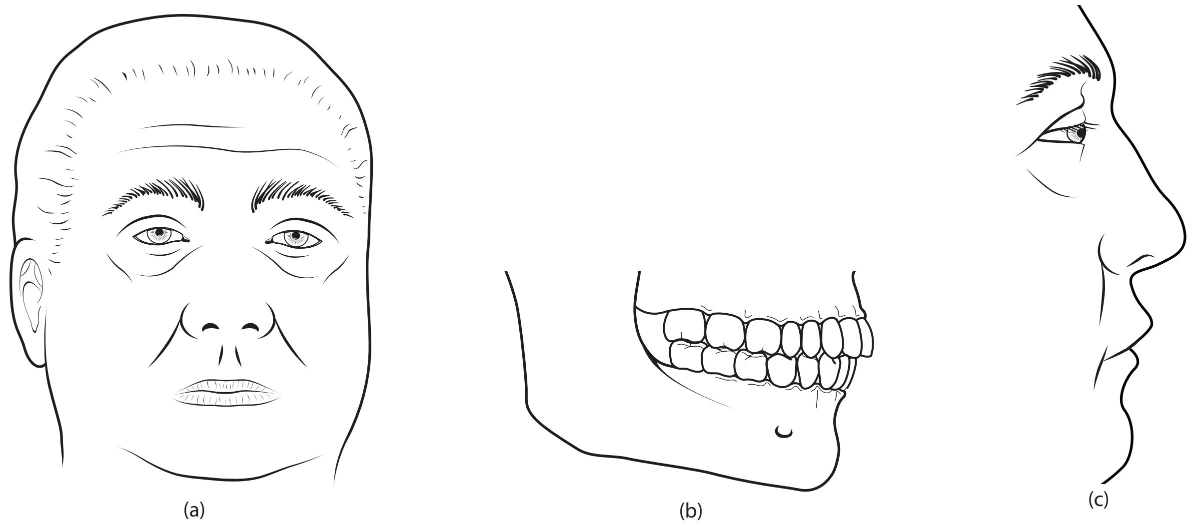


Figure 79.1 (a–c) Obese, retognathic male, lateral cephalometric film.

EVALUATION

- Medical and sleep history
- Polysomnogram
- Head and neck evaluation, neck circumference
- Body habitus
- Fibre optic nasopharyngoscopy Muller manoeuvre (Figure 79.2)
- Nose: septum, turbinates, nasal valve
- Intranasal examination via fibre-optic nasopharyngoscopy

INTRAORAL: OROPHARYNX, UVULA, TONSILS, BASE OF TONGUE

- Fujita classification of obstructive regions
  - Type I palate (normal base of tongue)
  - Type II palate and base of tongue
  - Type III base of tongue (normal palate)
- Radiographic evaluation: lateral cephalometric film – radiographic analysis (Figure 79.3)

NORMAL CEPHALOMETRIC VALUES

- SNA: 82
- SNB: 80
- PAS: 11
- PNS: P-35 mm
- MP: hyoid 15 mm

NON-SURGICAL MANAGEMENT

- Weight loss
- Sleep hygiene: elimination of caffeine late in the day

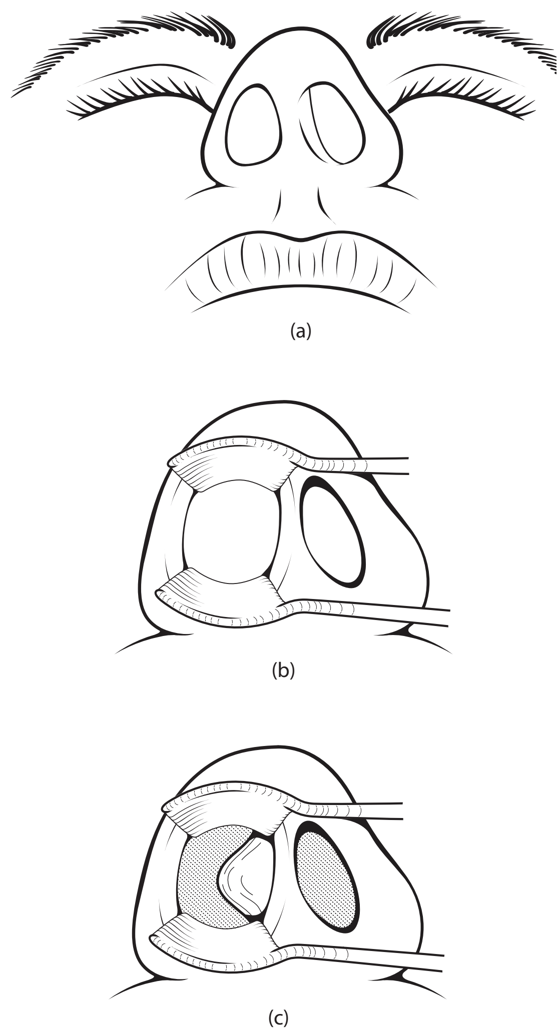


Figure 79.2 (a–d) Nasal examination and nasopharyngoscopy. (*Continued*)

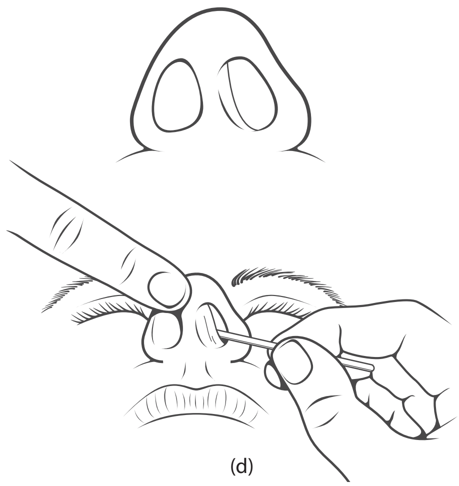


Figure 79.2 (*Continued*) (a–d) Nasal examination and nasopharyngoscopy.

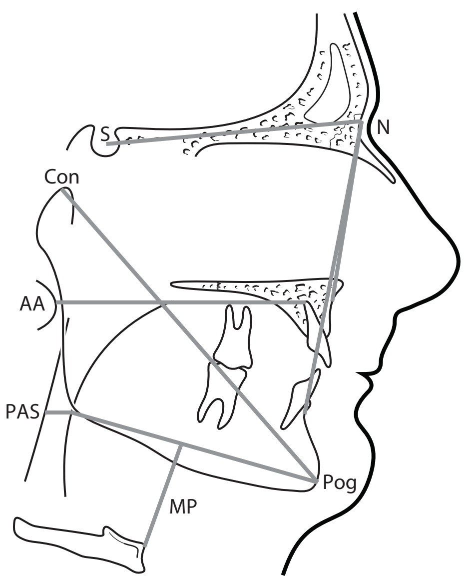


Figure 79.3 Lateral cephalometric film tracing.

- Avoidance of excessive exercise prior to sleep
- Sleeping with the head elevated reduces upper airway closure.
- Sleeping in the lateral recumbent or prone position is helpful.
- Safety pinning a tennis ball in a sock to the sleep garment is helpful in preventing sleep in the supine position.
- Avoidance of alcohol prior to sleep lessens obstructive events.
- Sedative agents can worsen obstruction.
- Smoking increases upper airway resistance through increased mucosal oedema.
- Pharmacologic supplemental O_2 is of questionable benefit. Apnoea may be prolonged in hypercapneic individuals with supplement O_2.
- Protriptyline may reduce obstructive events by diminishing rapid eye movement (REM) sleep.
- Supportive airway muscle tone may be increased.
- Protriptyline reduces subjective daytime somnolence.
- Multiple side effects related to anticholinergic properties limit protriptyline use.
- Serotonin uptake inhibitors may increase upper airway muscle tone, particularly in REM sleep.

MECHANICAL DEVICES

Nasal dilators may decrease upper airway resistance. Intra- and extra-nasal dilators only help a few select patients with nasal airway issues. Nasopharyngeal airways have limited utility because of poor tolerance.

Mandibular repositioning devices are helpful in mild to moderate cases (Figure 79.4).

Continuous positive airway pressure devices (CPAPs): Nasal CPAP remains the first line of treatment of obstructive sleep apnoea (Figure 79.5).

MODE OF ACTION

Nasal CPAP pneumatically stents the airway open during sleep (Figures 79.6 and 79.7).

GENERAL CONSIDERATIONS REGARDING CPAP MANAGEMENT

Initiation of CPAP therapy should commence within a sleep lab, monitored during polysomnography. Airway pressures should be increased to the level necessary to overcome obstruction. Proper instruction is critical to proper utilization. Compliance is also critical. The device must be worn all night to correct the ill effects of obstructive sleep apnoea on sleep architecture.

COMPLIANCE WITH CPAP THERAPY

Studies have shown that refusal rates for prescribed CPAP therapy range from 58% to 80%. Objective evaluation for compliance shows that only 40% of patients use nasal CPAP for at least 4 hours for seven nights out of ten. Poor compliance can usually be attributed to intolerance of the device.

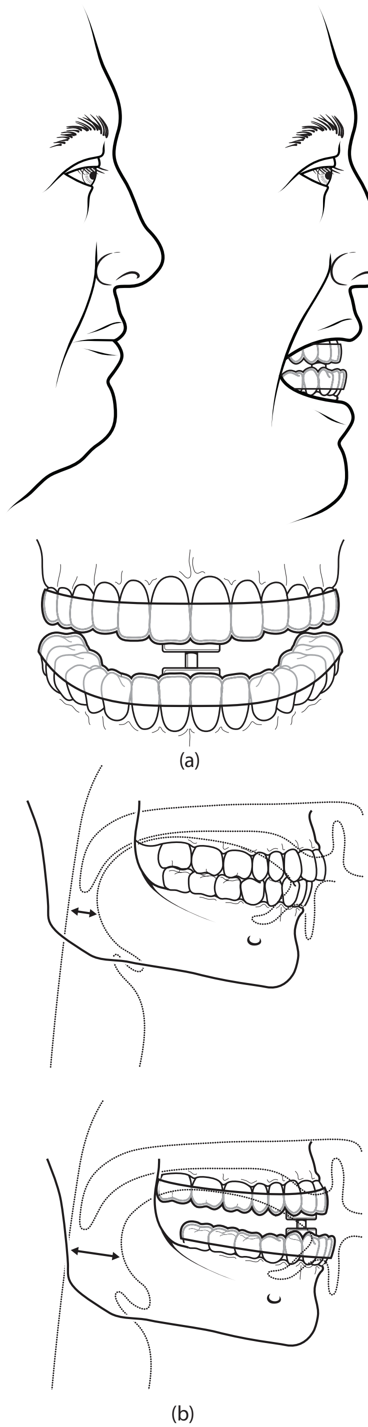


Figure 79.4 (a and b) Mandibular repositioning device, lateral film tracing of dental device in place.

SURGICAL MANAGEMENT OF OBSTRUCTIVE SLEEP APNOEA

Indications for surgical intervention failure of non-surgical measures include

- Intolerance of nasal CPAP
- Excessively high CPAP pressures
- Rationale and surgical goals

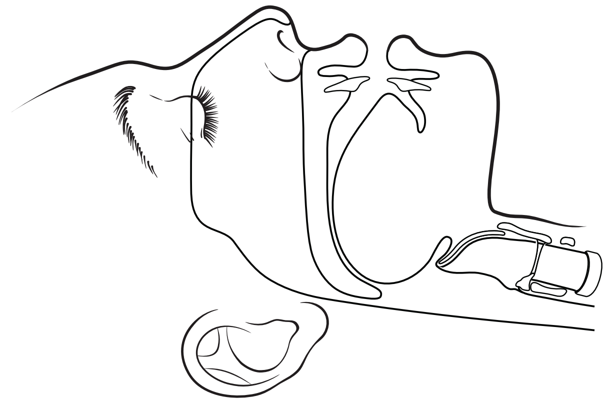


Figure 79.5 Lateral view of airway whilst asleep with airway collapse.

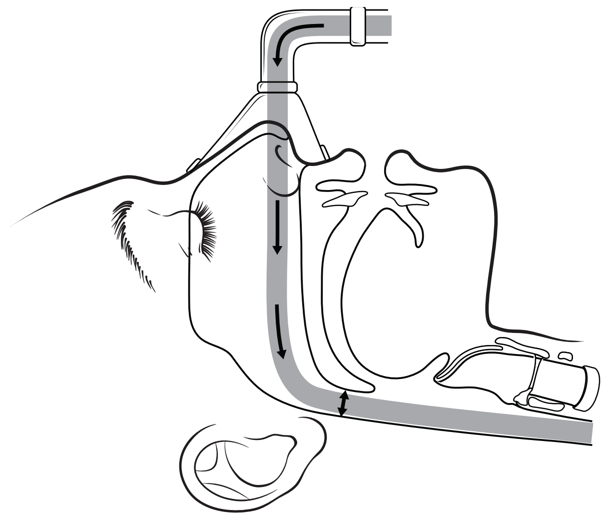


Figure 79.6 Lateral view with continuous positive airway pressure devices (CPAP) and airway pneumatically stented open.

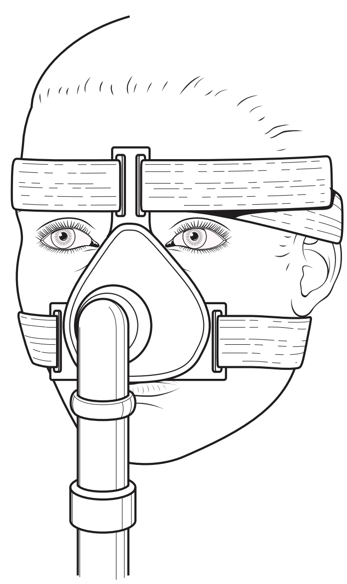


Figure 79.7 CPAP device in place on a patient.

The goal of surgery should be a cure of the disease. The particular surgery should be directed at the site of obstruction.

Powell–Riley advocated a staged approach to surgery.

Phase I therapy is directed towards the upper airway. The simplest and most conservative option is considered at a specific anatomic region only when obstruction exists there.

- Nasal regions: Correction of nasal obstruction directed at the specific deformity: nasal valve deformities, septum, turbinates.
- Pharynx: Uvulopalatopharyngoplasty (UPPP), tonsillectomy, chemical sclerosis.
- Hypopharynx: Advancement of tongue base through genioglossus advancement, infra-hyoid myotomy and suspension.
- Tongue reduction through partial glossectomy, laser reduction and temperature-controlled radiofrequency reduction.

Phase II therapy utilizes maxillofacial skeletal advancement referred to as mandibulo-maxillary advancement (Figure 79.9).

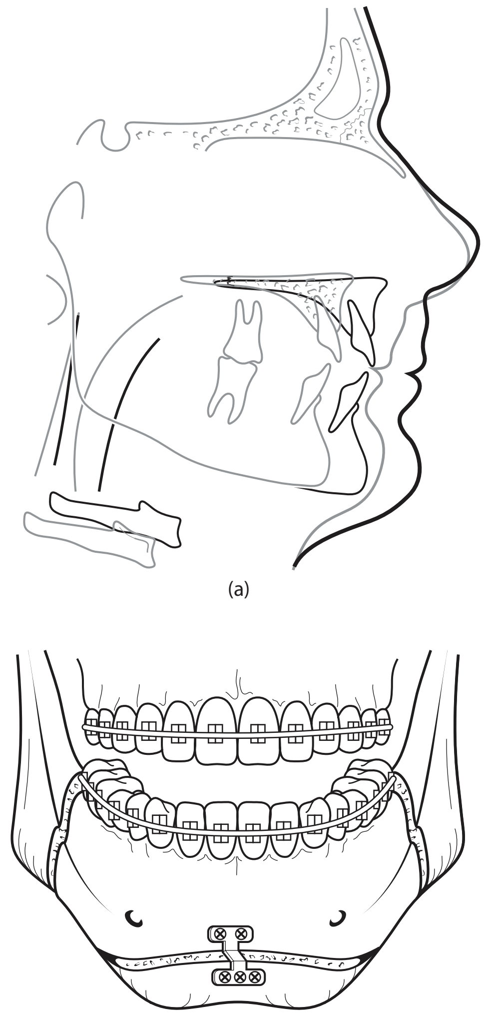
Pre-surgical preparation involves obtaining accurate dentofacial records through plaster casts of the jaws. The dental models must be mounted on an articulator (Figure 79.8).

In the pre-surgical planning the mandible is advanced maximally. This is usually about 10–12 mm depending on the patient and bony morphology of the mandible. The maxilla is then advanced to achieve the original maxillary–mandibular dental relationship. Cephalometric evaluation of the genial region is considered to allow maximal advancement with facial aesthetics in mind. An acrylic dental splint is fabricated to allow the desired repositioning of the mandibular dental model (Figure 79.10).

SURGERY

General nasal endotracheal anaesthesia is required. A hypotensive anaesthetic technique reduces blood loss. Patients with obstructive sleep apnoea syndrome have airways which can present challenges to intubation. Consequently, jet ventilation equipment must be available. An awake fibre-optic intubation may be necessary to secure the airway. It is critical that the anaesthesiology team be competent in the management of the difficult airway.

After securing the endotracheal tube, the patient must be padded, the arms tucked and pneumatic compression devices placed on the lower extremities to prevent deep venous thrombosis. Surgery is directed to the mandible first. Local anaesthetic with epinephrine is injected along the anterior ramus in a standard fashion. The incision extends laterally along the mandibular body region and terminates in the molar region. A full-thickness mucoperiosteal flap is elevated exposing the lateral



(a)

(b)

Figure 79.8 (a) Lateral view of pre- and post-MMA diagram. (b) Post-operative panoramic view. Note increase is posterior airway space (PAS).

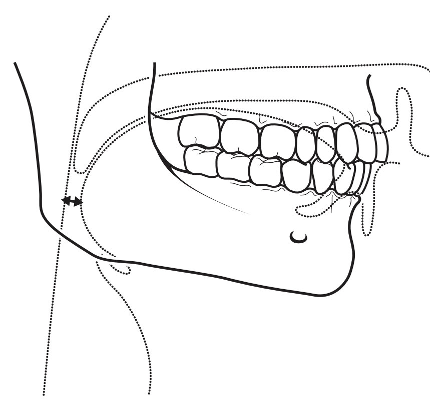


Figure 79.9 Lateral cephalometric tracing to show posterior airway measurement.

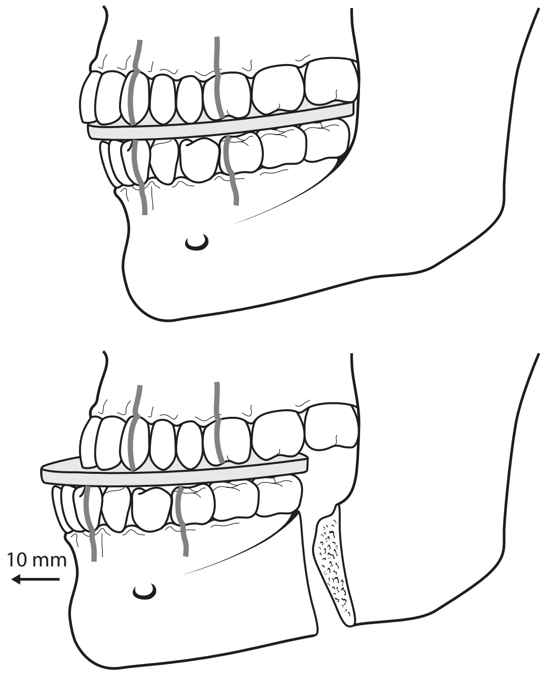


Figure 79.10 Dental models and surgical splint.

ramus and body region. Dissection is then directed along the medial ramus region taking care to protect the inferior alveolar neurovascular bundle. A forked retractor is extended up the anterior ramus to the coronoid. A clamp is then used to retract the tissues. A horizontal osteotomy is then made through the medial cortex. The osteotomy then is continued anteriorly to the body of the mandible, staying medial to the external oblique ridge. It terminates in the first or second molar region depending on the amount of anterior movement required. A vertical osteotomy is then made in lateral body. A sagittal split is then made and the segments freely mobilized. The inferior alveolar nerve is gently mobilized from the proximal segment (Figure 79.11).

The acrylic splint is then affixed to the teeth and the jaws are wired shut and into the new desired occlusion.

The mandibular condyles are then seated into the most posterior–superior portion of the glenoid fossa. The bony segments are then clamped together and rigidly fixed together with titanium bone plates and/or screws.

The jaws are then released and the occlusion and bony segments are checked for accuracy and stability with the condyles seated.

Attention is then directed to the maxilla. Once again, local anaesthetic with epinephrine is injected in the area of planned surgery (Figure 79.12).

A modified incision is then made in the anterior maxillary vestibule with the electrocautery unit from the anterior maxilla and terminating in the zygomatic buttress region. A full-thickness mucoperiosteal flap is elevated exposing the anterior maxilla. The anterior nasal spine is exposed and the nasal floor mucosa is elevated.

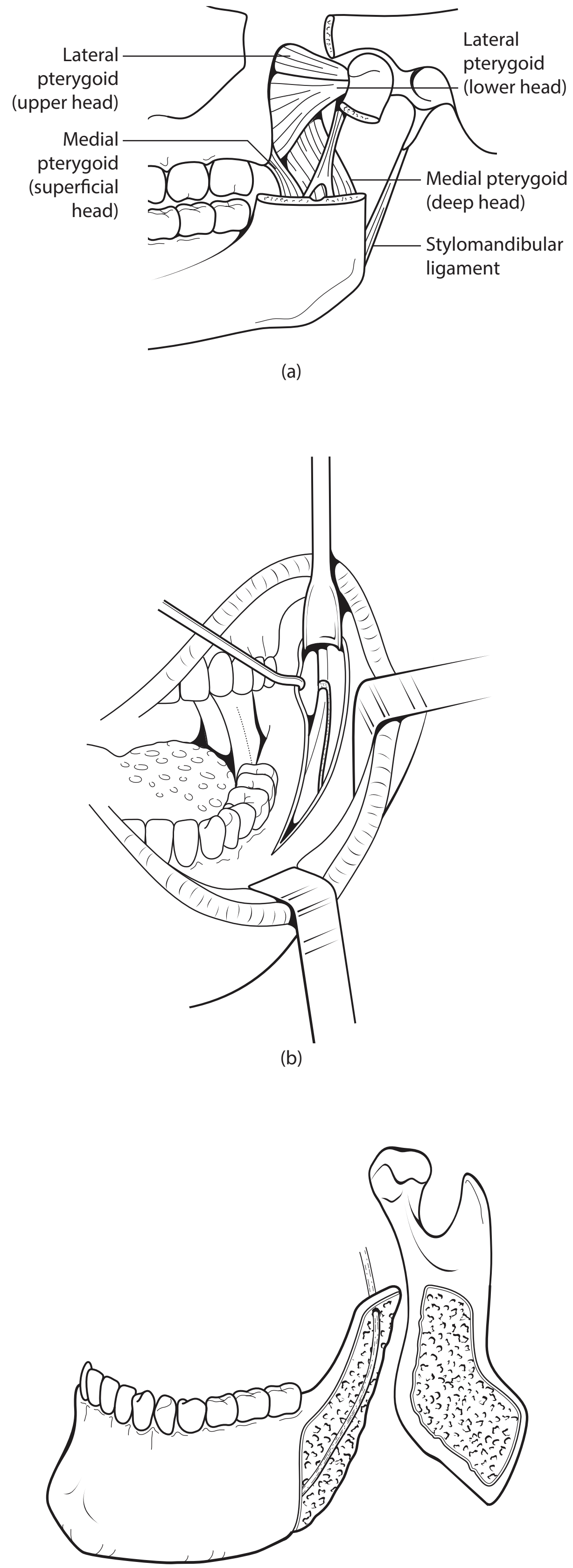


Figure 79.11 (a–c) Sagittal split advancement of the mandible, manually mobilize segments.

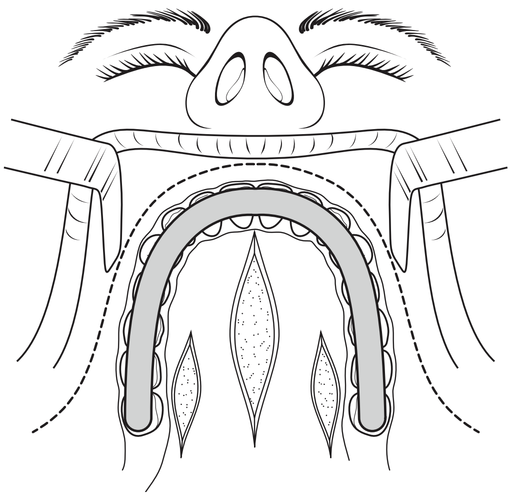


Figure 79.12 Attention is then directed to the maxilla. Once again, local anaesthetic with epinephrine is injected in the area if surgery is planned.

A horizontal osteotomy is made from the lateral pyriform rims extending posteriorly to the malar region. Osteotomes are then used to osteomotize the lateral nasal bony walls. A guarded osteotome is then used to achieve nasomaxillary separation. Finally, a curved osteotome is used to achieve pterygomaxillary separation.

Disimpaction forceps are then used to down fracture the maxilla. The maxilla must be freely mobilized so that it will passively advance to its new anterior position.

The jaws are then brought back into the original occlusion taking great care to seat the mandibular condyles again. The jaws are wired together again. The advancement of the maxilla is such there is little bony overlap and this can result in poor stability. This can be addressed with the mortizing of a piece of cadaveric cortical bone between the segments (Figure 79.13).

Rigid fixation is then used in the pyriform rim and malar buttress regions with titanium plates and screws.

A demineralized bone matrix can be applied to the osteotomy sites along with a restorable membrane. This modification can result in a more rapid bony healing and lessens sinusitis issues from a large gap in the bony segments.

Whilst the jaws are still wired together, attention is directed to the genial region. Once again, local anaesthetic with epinephrine is injected in the planned area of surgery.

An incision is then made in the labial mucosa and then advanced in a stepped fashion to the anterior genial region. The genial region is degloved. A horizontal osteotomy can be performed in the standard fashion (Figure 79.14) or just the segment containing the genial tubercles (Figure 79.15).

It is critical that with each technique, the genial tubercles be included in the mobilized segments.

The segment including the genial tubercles is advanced and secured with rigid fixation. Demineralized bone matrix may be used to fill any osteotome gaps (Figure 79.16)

If the chin contour would be damaged by an advancement genioplasty, the genial tubercles can be advanced in isolation (Figure 79.17).

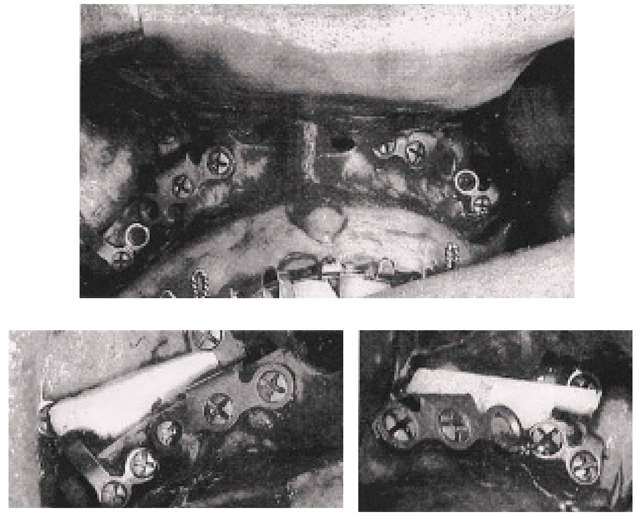


Figure 79.13 Maxilla with bone graft in place.

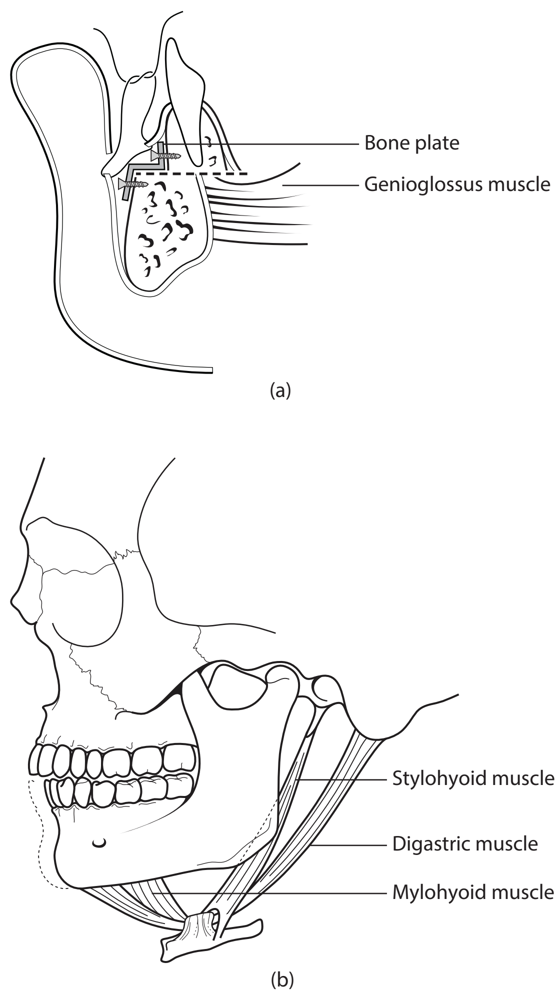


Figure 79.14 (a–c) Geniotomy. (*Continued*)

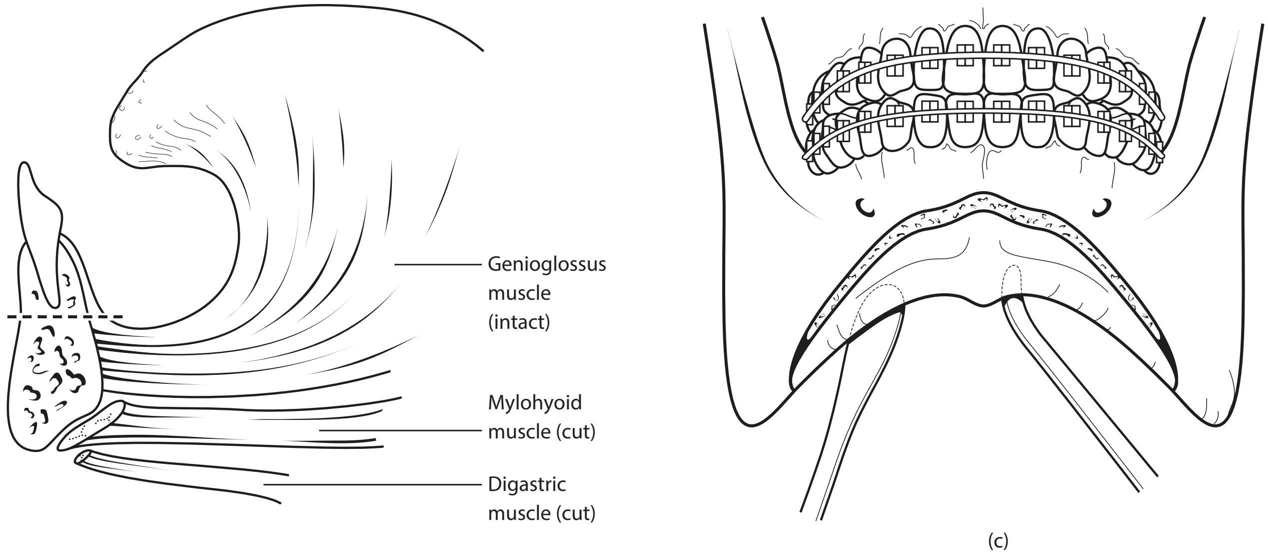


Figure 79.14 (*Continued*) (a–c) Geniotomy.

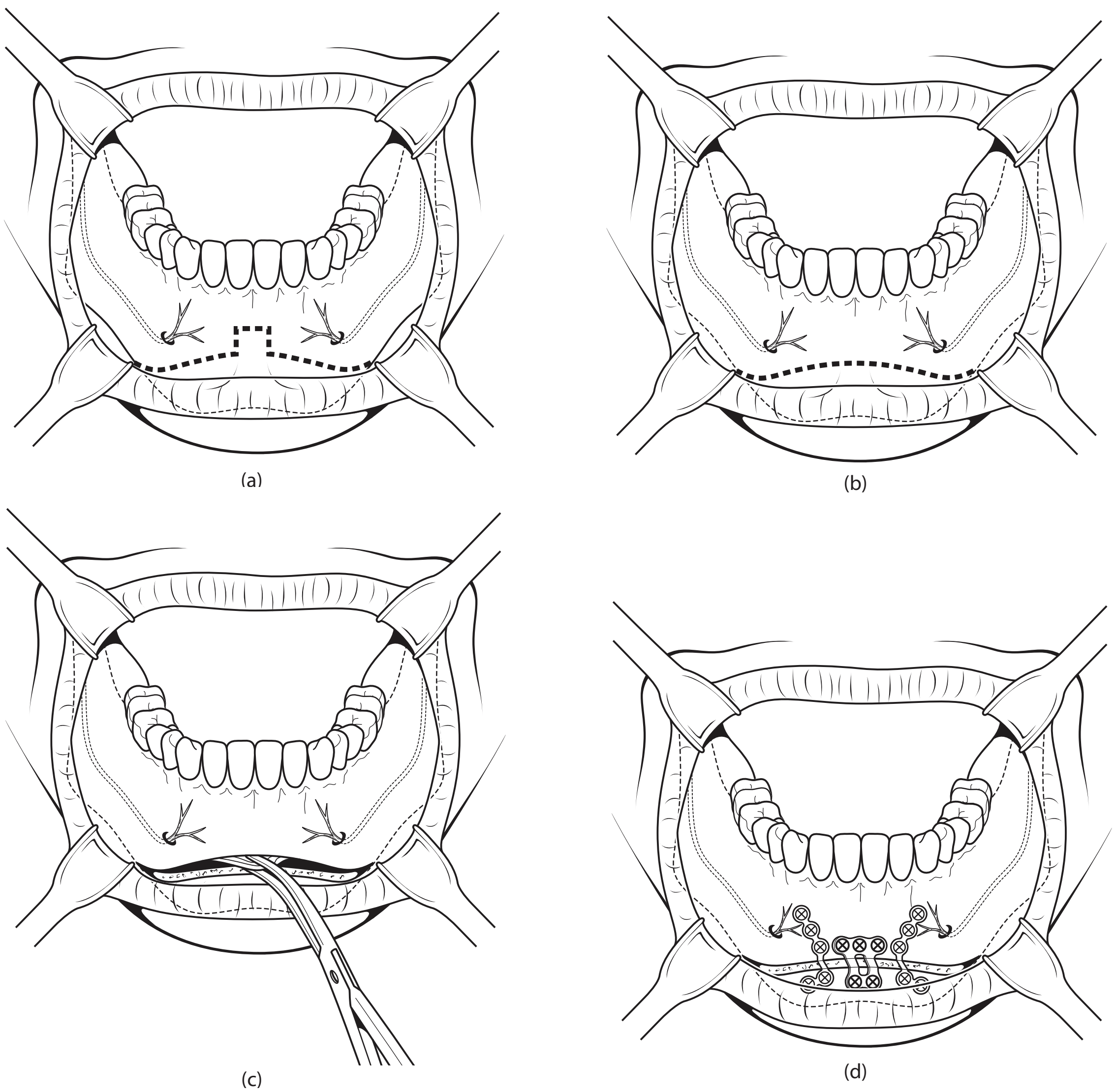
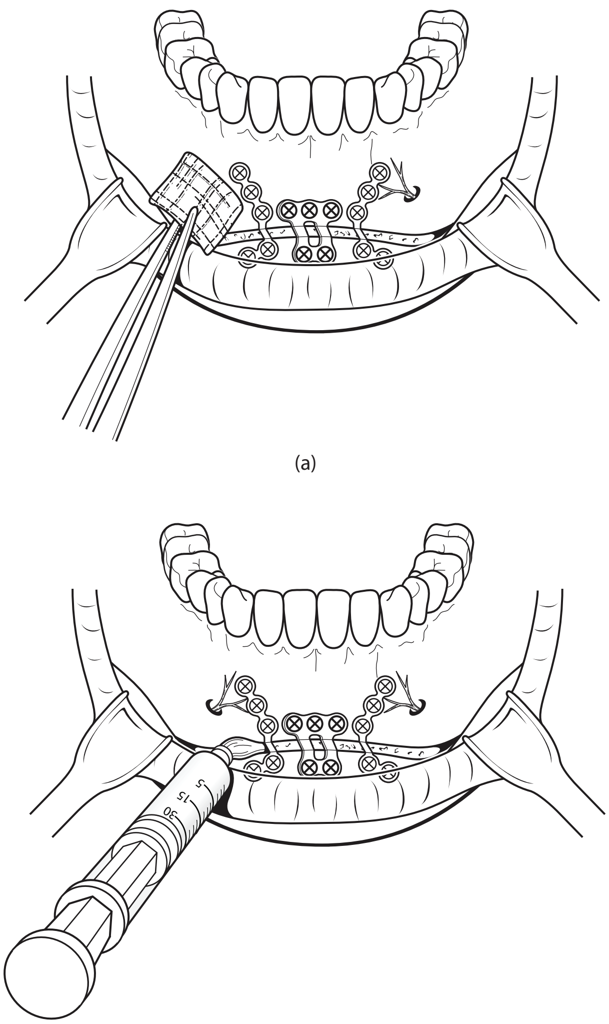


Figure 79.15 (a–d) High modified geniotomy to include genial tubercles.

Attention is then directed to the hyoid region. The area of planned incision directly overlying the hyoid bone is marked with a pen. An incision is then made in the skin with the scalpel. Haemostasis is obtained. Blunt dissection is continued until the hyoid is encountered. The hyoid bone is exposed. Then, infra-hyoid muscles are released. Two permanent braided synthetic nonresorbable sutures are then passed around and under the hyoid laterally and passed subcutaneously up into the genial region. Two holes in the mobilized genial segment are made with the drill and the sutures passed through them. The sutures are then passed around and under the hyoid laterally and passed subcutaneously up into the genial region. Two holes in the mobilized genial segment are made with the drill and the sutures passed through them. The sutures are then tightened to the desired level of hyoid suspension and tied securely.

A modification of the hyoid suspension procedure shows promise.



(a)

(b)

Figure 79.16 (a and b) Demineralized bone matrix to fill osteotomy gap.

In this technique, the inferior body of the hyoid is stripped of muscle and then advanced over the thyroid cartilage and sutured to its superior aspect. The superior hyoid musculature is left intact.

Wound closure of the mandibular and hyoid regions can be accomplished in a standard fashion. However, closure of the maxillary wounds merits some elaboration. The standard technique using an alar cinch suture in the lateral nasal region to prevent unaesthetic widening of the nose should be used with caution. Since this surgery is for an airway problem, the alar cinch should not be so tight as to narrow the nasal airway.

The maxillary mucosa closure should incorporate a V-Y advancement to prevent wound contracture and undesired shortening of the upper lip.

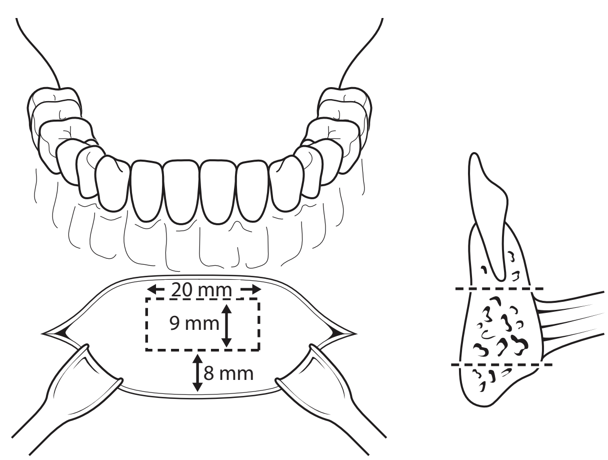
After wound closure, a pressure dressing should be adapted to the mandibular regions.

Closure of the incision of the hyoid region is performed in a standard fashion after haemostasis has been obtained.

It is prudent to keep these patients intubated and in the intensive care unit overnight. As their clinical status dictates, they can usually be weaned and extubated on post-op day 1. It is also wise to keep them in the intensive care unit one additional night after extubation.

The post-surgical management of the sleep apnoea patient is similar to other orthognathic patients, with a few exceptions. Their airways will hopefully be greatly improved after surgical intervention. Nonetheless, post-surgical oedema will impact their airway in a negative fashion until it resolves. In most cases, the airway is so greatly improved that nasal CPAP is not necessary, even in the presence of post-surgical oedema.

In the personal experience of the authors, the post-surgical management of sleep apnoea surgery patients has been remarkably trouble-free. This supports the concept that once the airway is open for normal respiration during sleep, the associated co-morbidities are often ameliorated.



(a)

Figure 79.17 (a-d) Genial tubercle advancement. (*Continued*)

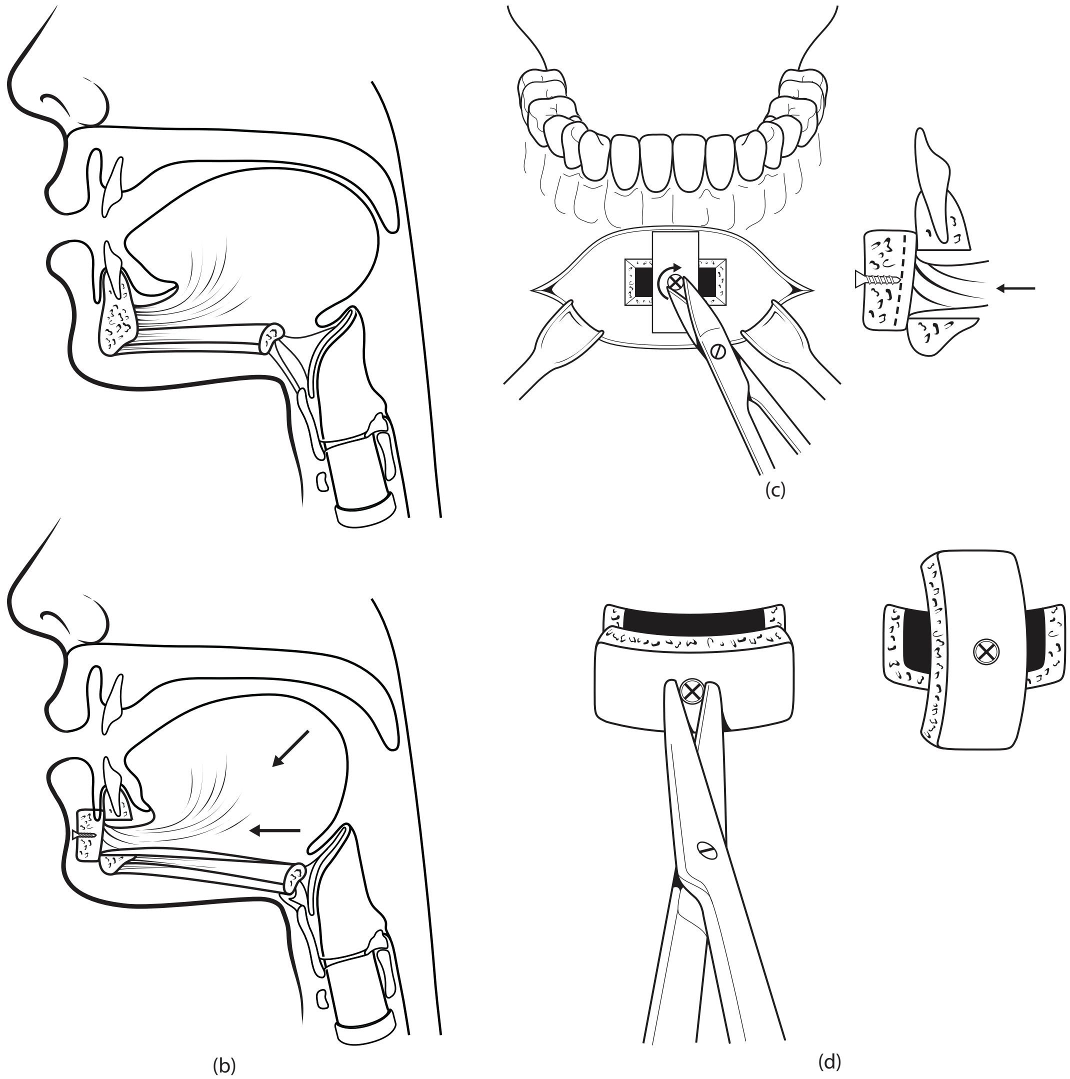


Figure 79.17 (*Continued*) (a-d) Genial tubercle advancement.

SUGGESTED READINGS

Kribbs NB, Pack AI, Kline LR, Smith PL, Schwartz AR, Schubert NM et al. Objective measurement of patterns of nasal CPAP by patients with obstructive sleep apnea. *Am Rev Respir Dis*. 1993; 149: 287–288.

Powell N, Riley RW, Guilleminault C and Murcia GN. Obstructive sleep apnea, continuous positive airway pressure and surgery. *Otolaryngol Head Neck Surg*. 1988; 99: 362–369.

Riley R, Powell N and Guilleminault C. Cephalometric roentgenograms and computerised tomographic scans in obstructive sleep apnea. *Sleep*. 1986; 9: 514–515.

Riley R, Guilleminault C, Powell N and Derman S. Mandibular osteotomy and hyoid bone advancement for obstructive sleep apnea: A case report. *Sleep*. 1984; 7: 79–82.

Top tips

- Freely mobilize the osteotomized segments for passive advancement.
- Use bone grafts in the maxilla along with demineralized bone matrix and resorbable membranes to aid in complete bony union.
- Advance the hyoid so far to allow for some relapse, and still stent the airway open.
- Keep the patient sedated and on the ventilator for the first post-operative night.

SECTION XI

FACIAL AESTHETIC SURGERY

80

Nonsurgical techniques: Botox and fillers

N RAVINDRANATHAN

CONTENTS

INTRODUCTION

Methods of restoring facial aesthetics in a non-invasive or minimally invasive way is now well established. The armamentarium of the modern cosmetic surgeon includes Botox, fillers, peels, lasers and radiofrequency wave application. The skin is a major indicator of a person's age and health. With ageing, the dermis becomes thinner and the epidermis becomes either thicker or thinner. There is, in addition, bone resorption, the appearance of furrows, wrinkles, crow's feet and platysmal bands in the neck. One of the main reasons why patients seek treatment for age changes is to restore soft-tissue volume, contour and absorption or reduction of wrinkles with the aim to restore a youthful appearance.

INDICATIONS

- Soft-tissue atrophy, e.g. thinning of the lips
- Appearance of crow's feet, glabella furrows
- Lipoatrophy of the face, e.g. cheeks
- Presence of all the features of ageing in the face and neck
- Pigmentary dyscrasia of the skin associated with ageing
- Bony resorption leading to reduction of facial bony contour, loss of facial height

CASE SELECTION AND PRE-PROCEDURE PREPARATION (GENERAL PRINCIPLES)

- Any patient who wishes to look younger is a potential candidate for rejuvenation by non-invasive methods provided he or she fully understands what is realistically possible to achieve and accepts the potential complications.
- In general, smokers and those who indulge in heavy or regular consumption of alcohol are not good candidates.
- Patients with adverse medical histories, for example uncontrolled diabetes, those on warfarin, abnormal bleeding disorders and those prone to developing frequent herpetic infections in the peri-oral region are not good candidates.

Medications containing aspirin and nonsteroidal anti-inflammatory agents should be discontinued at least 5–7 days before any minimally invasive surgical procedure. Likewise, herbal formulations, gingko biloba, ginseng, garlic and ginger should also be discontinued. Minimally invasive procedures such as injection of fillers intradermally should be avoided during active acne eruptions.

Patients should be given a detailed explanation regarding the likely outcome of the procedure and techniques involved, materials being used and their known adverse effects before any procedure is undertaken.

FILLERS

Soft-tissue augmentation may be accomplished by surgery or intradermal injection of synthetic or biological materials. Soft-tissue augmentation using various fillers has gained enormous popularity as there is no recovery time and it can be conveniently undertaken at the end of a week to allow recovery during a weekend.

IDEAL PROPERTIES OF A FILLER

Ideally, it should be of non-animal origin, biocompatible, biodegradable, having low risk of allergic reaction, easy to use and having minimal side effects such as bruising, infection, migration and tissue reaction.

An injectable filler should be able to restore facial contour. There are several fillers available and they include the following:

- Autogenous fat
- Autogenous dermis
- Synthetic poly-L-lactic acid
- Liquid silicone
- Collagen
- Polymethyl methacrylate microspheres
- Hyaluronic acid derivatives
- Expanded polytetrafluoroethylene

PRINCIPLES OF AUTOGENOUS FAT INJECTION AS FILLERS

- Autologous fat is harvested with an open tipped blunt cannula under tumescent local anaesthesia.
- Harvested fat is transferred to 1-mL syringes for injection into the areas concerned.
- Injection of fat into the deep tissues of the face is carried out using a small bore blunt cannula.
- Any patient who wishes to restore their facial contour would be a good candidate for pan facial fat augmentation.
- Any patient who has a recent history of deep venous thrombosis, pulmonary embolism, compromised liver function, allergy to lignocaine, coagulopathy or inability to stop anticoagulant drugs is contraindicated for fat augmentation.

TECHNIQUES OF FAT HARVESTING AND TRANSFER

1. Pre-operative assessment using photographs: discuss with the patient areas for augmentation. If adjunctive microliposuction is planned, e.g. neck, jowls, indicate it on the photograph. An A4 photograph permits a large image for discussion. Take frontal, lateral and inferior oblique views.
2. Laboratory work-up includes pregnancy test if premenopausal, clotting profile, full blood count, renal and liver profiles.
3. An antibiotic is administered orally or intravenously 1 hour before the procedure. A first generation cephalosporin is preferred.
4. Tumescent local anaesthesia solution is prepared using 500 mL of Ringer's Lactate, 0.5 mg of epinephrine, 1% lignocaine 25 mL. Anaesthetic solution is administered into the prospective donor site for fat harvest (Figure 80.1). I prefer the anterior abdominal wall (Figure 80.2) or outer thigh. When the local anaesthetic has taken effect, make an incision with a size 11 blade as a stab and introduce a curved haemostat to create a subcutaneous tunnel (Figure 80.3). Other areas which can be used are hips or posterior waist. Subsequently, the tumescent solution is infiltrated (Figure 80.4). After injection wait 15–20 minutes.
5. A low negative pressure is created in a 10-mL syringe. An open tipped cannula (Figure 80.5) is attached to the syringe and is inserted into the donor site through the same small stab incision. The cannula is moved back and forth within the donor site 1-cm below the skin surface. This will help to avoid surface

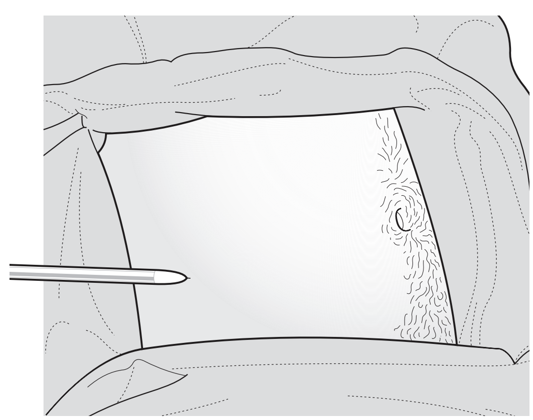


Figure 80.1 Infiltrating local anaesthesia.

Figure 80.2 Anterior abdominal wall donor site.

Figure 80.3 Creating a subcutaneous tunnel to inject tumescent solution.

Figure 80.4 Infiltration of tumescent solution.

Figure 80.5 Aspiration of fat using 10-mL syringe from anterior abdominal wall.

irregularities. The plunger of the syringe containing the harvested fat is released, the cannula removed and the syringe is capped (Figure 80.6) and allowed to stand in a test tube. Centrifuge the collected fat in 10-mL syringes placed in a centrifuging machine at 3400 rpm for 20 seconds. The centrifuged fat will separate from an infranatant which consists of, at the top, liquid triglyceride, blood and tumescent fluid, and below, the fat (Figure 80.7). Carefully decant off the top layer. Transfer the fat from the 10-mL syringes into 2-mL syringes using a connector (Figure 80.8). From these syringes fat is injected into the recipient sites which have been marked at the commencement of the procedure (Figure 80.9).

6. Injection of fat is carried out with blunt cannulas and the injection is done as a 'layering' technique (Figures 80.10 through 80.12). If injection is done in the forehead, small incisions are made at the hairline. Injection is done in a plane above the galea. Fat can be transferred to the glabella, forehead, upper eyelids and brow. Fat can also be injected into the lower eyelid, for example when too much fat has been removed during blepharoplasty or tear-trough deformities seen in ageing. In this area, fat is injected in a subcutaneous plane.
7. Fat augmentation of the buccal area is via a stab incision made anterior to the upper ear and is in a superficial plane making radial fan-like movements. Fat

Figure 80.6 Fat in harvested syringes.

Figure 80.7 Harvested fat in 10-mL syringe allowed to stand vertically, supernatant fluid is injected.

augmentation can also be carried out to enhance the lower jaw border, chin prominence, cheek prominence by infiltration in a deep plane and layering in a plane superficial to this. In the peri-oral area, vertical ageing lines and lips can be augmented. Prior to introduction of the fat to augment the lips, carry out an incision between the muscle and the skin and introduce fat into this plane. The vermilion of the lips can also be enhanced and for this purpose use a 20-gauge needle. Typically, the author uses approximately 3 mL for the upper and 2–3 mL for the lower lip.

8. Fat augmentation can also be successfully used in the nasolabial creases and labiomental creases (Figure 80.13).

Figure 80.8 Harvested fat in 10-mL syringe being transferred from 10-mL syringe to 2-mL syringe via a connector.

Figure 80.9 Recipient sites – bilateral nasolabial folds, subcutaneous atrophy (variant of Romberg's disease).

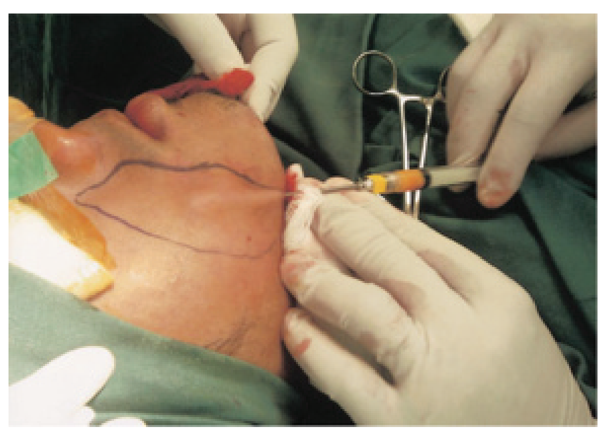


Figure 80.10 Harvested fat being injected into recipient site, demonstrating the layering technique.

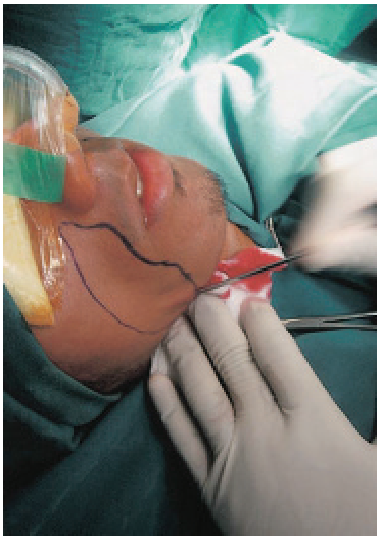


Figure 80.11 Harvested fat being injected into recipient site, demonstrating the layering technique.

Figure 80.12 Injection of harvested fat into recipient area.

POST-OPERATIVE INSTRUCTIONS AND CARE AFTER FAT TRANSFER

- As oedema after fat transfer by blunt infiltration can be profound, prescribe oral steroids in a dose of 40-mg prednisolone 1 hour before the procedure and a daily dose post-operatively for 2 days.
- Ice packs for 48 hours for at least 20 minutes/hour.
- Medications such as aspirin, plavix, blood thinning supplements or vitamin E should be avoided for 72 hours.
- No active physical exercise, such as jogging, weight training or swimming, should be undertaken for 1 week.

Figure 80.13 Appearance after injection of fat into recipient areas (4 weeks after injection).

COMPLICATIONS

- Oedema, contour irregularities, echymosis (usually temporary).
- Infection and submandibular lymphadenitis.
- Fat embolism resulting in cerebral infarction and or sudden blindness (a rare complication).
- Fat cysts or hard nodules. These are treated initially by an injection of triamcinolone. If this does not resolve after two injections, a direct excision is carried out.
- Post-inflammatory pigmentation is sometimes seen and it is best treated upon recognition with hydroquinone 4% for 4–12 weeks. If there is no response, intensity pulse light (IPL) can be used and, with two or three sessions, it should resolve.

SYNTHETIC FILLERS

Polymers of lactic acid are currently available commercially as injectable poly-L-lactic acid, a biodegradable polymer. They are in the same family of aliphatic polyesters such as glycolic and citric acid. They are available as microparticles measuring 40–63 μm in diameter suspended in sodium carboxymethyl cellulose. Upon injection into the subcutaneous tissue or deep intradermal space, it undergoes gradual degradation over a period of years and there is increased collagen fibre formation around the microparticles with the passage of time.

It is available as a lyophilized powder which is reconstituted with 3–5-mL sterile water. The powder is mixed thoroughly with water to achieve a homogenous mix and the preparation is carried out preferably 2 hours before the injection. The author prefers to use 5-mL dilution except in cases where there is marked lipoatrophy when 3-mL dilution is used. I usually apply

a eutectic mixture of local anaesthetics (EMLA) cream topically 45 minutes before injection or give a local anaesthesia. Upon injection, a sculpting massage is carried out for approximately 2–3 minutes. The injection can be repeated at 4-week intervals.

The author has used this product as a filler for deep nasolabial folds, as a subperiosteal injection over the dorsum of the nose for subtle augmentation and subperiosteally in the lower orbital rim for tear-trough deformities. Granuloma formation has been encountered in two of ten patients. The granuloma was difficult to treat and hyaluronic acid derivatives are now used instead.

For several years, bovine collagen was the gold standard as a soft-tissue augmentation material. However, it is only short-lived and serious hypersensitivity reactions have been reported. To overcome this, human-based collagen has been used.

Hyaluronic acid-based fillers are ideal because they are less immunogenic and have a longer duration effect than collagen. Patient tolerability is good. Hyaluronic acid as smaller particles is marketed by Q-Med Uppsala as Restylane and larger particles as Perlane. Restylane usually lasts approximately 6 months and Perlane can last 6–12 months. The same company also produces hyaluronic acid of even greater size (Macrolane). The hyaluronic acid injections can be repeated at 4–6 month intervals. These fillers are a useful adjunct in facial cosmetic procedures. They very rarely cause allergic reaction. The US Food and Drug Administration (FDA) has approved hyaluronic acid (Restylane) as a filler for nasolabial fold augmentation. Injection-related side effects include bruising, erythema, pruritus and discolouration. Sometimes granulomas occur and they respond well to injection of corticosteroids followed by massage.

TECHNIQUE FOR NASOLABIAL FOLD AUGMENTATION

Prior to injection, the area is cleaned with an antiseptic solution. A local anaesthetic is used. The filler of hyaluronic acid origin is injected into the deep and mid-dermis with Perlane and subsequently Restylane is used for surface feathering. The material is injected while withdrawing the needle. Complications include bruising, bleeding, swelling and uneven surface irregularities (rarely), discolouration of skin, pruritus and delayed skin reactions.

SILICONE OIL

Silicone oil has been used in its injectable form for filling defects of the facial soft tissue in HIV positive patients who develop lipodystrophy. Use of silicone in its liquid form as a filler is controversial. Currently, the FDA has approved liquid silicone for retinal tamponade (a viscous compound of 5000 centistokes) manufactured by Bausch & Lomb, California. The persistence is longer according to particle size. Silicone liquid of 1000 centistokes manufactured by Alcon Labs, Fortworth, Texas, is also useful for soft-tissue augmentation. It is inexpensive, can be sterilized, does not permit bacterial growth and it can be stored without refrigeration. Currently, there are multicentre trials in progress using liquid silicone oil for soft-tissue augmentation. To avoid complications silicone should only be used in small amounts.

Indications for using silicone oil

- Contour defects
- Photoageing resulting in rhytides
- Atrophy of skin following corticosteroid injections
- Linear scleroderma

Contraindications

- Do not inject large volumes
- Patients at increased risk of embolism
- Patients with autoimmune disorders
- Patients with multiple allergies
- Patients who have complications due to silicone injection by another practitioner

Technique of injection

1. Inject using microdroplet technique as very small amounts into deep dermis
2. Treatment can be repeated after 6 weeks

Complications

- Migration of injected silicone.
- Facial skin necrosis, granuloma formation, formation of nodules (Figure 80.14).
- When injected superficially, it produces erythema over the overlying skin and recurrent inflammatory oedema (Figure 80.15).
- Over the injected area, a definite demarcation appears.
- The only way to prevent complications is to use only small amounts of pure silicone oil.
- Delayed reactions such as rosacea and rosacea-like syndromes can develop years after injection. Likewise, granulomas can develop years later.

Treatment of silicone-induced granulomas

- Oral prednisolone starting with 40 mg/day and tapering over 10 days
- Intralesional corticosteroid injection starting at 5 mg/cm^3 and increasing up to 30 mg/cm^3 every 3 weeks
- Minocycline simultaneously 100–200 mg/day for up to 2–4 weeks

Figure 80.14 Injected silicone producing nodule over the glabella and granuloma at the tip of the nose.

Figure 80.15 Injected silicone producing erythema.

POLYMETHYLMETHACRYLATE MICROSPHERES (ARTEFILL, ARTECOLL)

This product has been approved by the FDA as a soft-tissue augmentation material. It is a suspension of polymethyl methacrylate microspheres in 3.5% bovine collagen. It is useful to fill subcutaneous atrophy and atrophy of the buccal fat pad. It is best to inject small amounts each visit in incremental doses 4–6 weeks apart as it is a permanent filler.

Complications

- Beading, ridging, formation of nodules.
- Granulomas and nodule formation can occur after years.
  The author has encountered this in a patient who had it injected 3 years previously. If the nodule does not respond to corticosteroid injection, excision would be the choice.
- Artecoll should not be used in areas of thin skin, e.g. lower eyelid.

Technique

- Artecoll should not be injected intradermally. It should only be injected subdermally.
- It is best to inject it in very small amounts incrementally.

Contraindications

- Allergy to bovine collagen
- Those prone to develop keloids

Note: As bovine collagen is the vehicle for the microsphere particles, allergy testing must be carried out prior to use.

POLYACRYLAMIDE HYDROGEL (AQUAMID)

In the last few years, the author has used this product as the preferred choice. It is supplied in 1-mL syringes as an injectable form containing 97.5% non-pyrogenic water. It is long lasting, biocompatible and does not migrate from the site of injection. It contains no animal extracts and has been authorized for sale in Europe since March 2001 and requires no prior allergy testing.

Indications

- Cheek remodelling
- Treatment of peri-oral wrinkles
- Lip augmentation (Figures 80.16 and 80.17)
- For elimination of nasolabial folds
- For correction of depressed scars (Figures 80.18 and 80.19)
- Treatment of deep wrinkles
- For subtle dorsal nasal augmentation

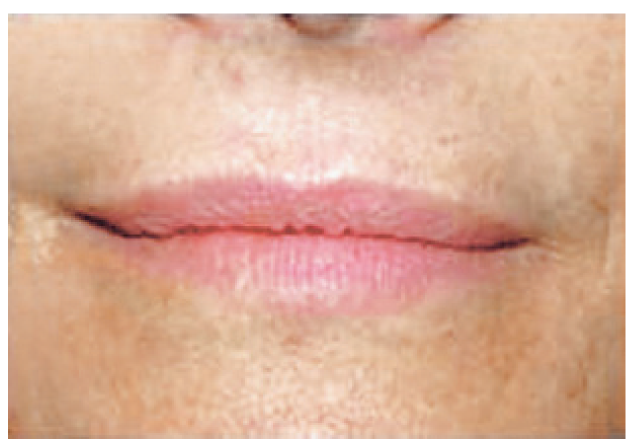


Figure 80.16 Pre-operative – pre lip augmentation.

Figure 80.17 Six months after lip augmentation with 'Aquamid' (polyacrylamide).

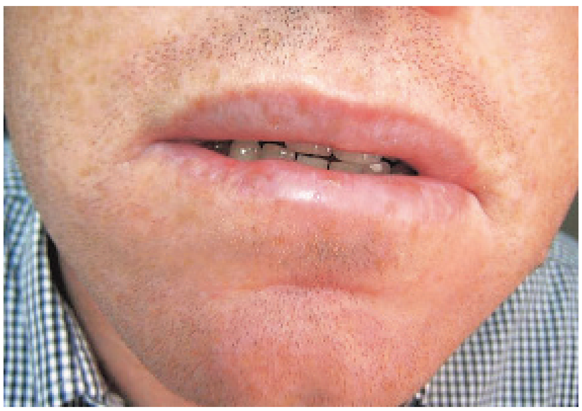


Figure 80.18 Lower right myomucosal deformity following traumatic injury.

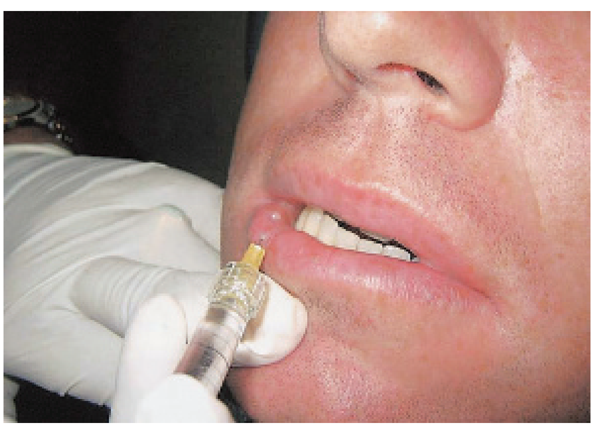


Figure 80.19 Injection of 'Perlane' (hyaluronic acid) into the lip deformity – submucosally.

Technique

- It is best injected under local anaesthesia by an appropriate nerve block. It is best to use a 27-gauge needle for injection.
- Injection must be carried out under sterile conditions.
- Inject while withdrawing the needle in a retrograde manner.
- After injection, perform gentle massaging.
- Do not overcorrect.
  If in doubt, add in increments as a touch up 1 week later.
- The gel should not be injected intradermally. Do not inject polyacrylamide gel into an area where another filler has been injected previously until absorption has been complete.

Contraindications

- Do not inject sites where there is active skin disease or inflammation.
- Do not inject in lactating mothers or during pregnancy.
- Injection when herpes labialis is present should not be carried out.

Post-operative instruction after injection

- Ice pack application locally for 48 hours for at least 20 minutes per hour for 12 hours.
- Avoid direct sun exposure for 24 hours.

Complications

- Bruising and oedema.
- In very few instances, allergic reactions have been reported.

Adverse reaction to dermal fillers and implications

In general, injectable fillers can result in adverse reactions and complications and are summarized below as follows:

- Reactions at the site of injection – pain, bruising, oedema, erythema, itchiness
- Infection
- Hypersensitivity reactions – erythema, nodules, formation of granulomas resulting in lumps (Figures 80.14 and 80.15)
- Discolouration may be as redness or hyperpigmentation
- Necrosis of the skin overlying the injected site
- Migration of injected implant
- Embolism
- Blindness

BOTULINUM TOXIN TYPE A (BOTOX)

Facial enhancement using Botox (Allergan Inc., Irvine, California) is a safe and effective procedure for the abolition of lines and wrinkles on the face. Lines typically occur due to muscular contractions of the facial muscles (Figure 80.20). Botulinum toxin type A can temporarily eliminate these lines and enhance the effect of laser

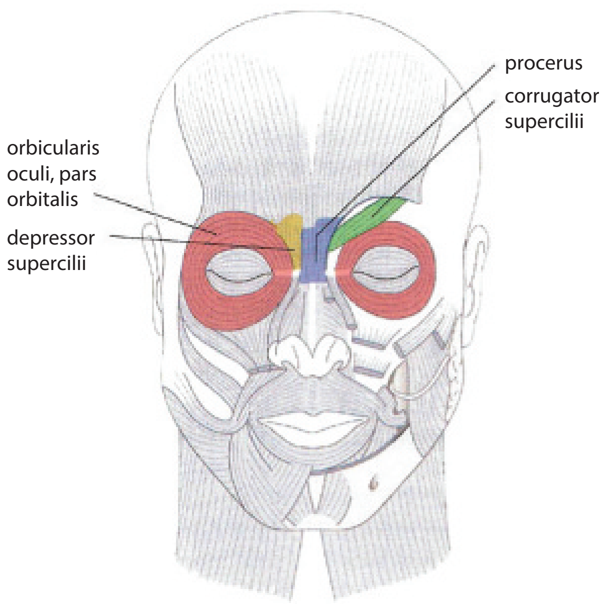


Figure 80.20 Showing facial muscles of the glabellar complex.

resurfacing procedures. It is now well accepted by cosmetic surgeons that pretreatment of wrinkles and lines due to hyperfunctioning of the muscles with Botox followed by laser resurfacing gives optimal results.

It has been observed that, in Asians, resurfacing results in troublesome pigmentary complications and hence it is not a good option for elimination of wrinkles and lines. Botox is the best primary line of treatment for abolition of these lines. In Caucasians, where skin resurfacing is undertaken for facial rejuvenation, rhytides can reappear after resurfacing, particularly in the glabella and crow's feet area.

PREPARATION AND RECOMMENDED METHOD FOR USAGE

Botox is supplied in a vial which contains 100 units of vacuum dried complex of neurotoxin (Figure 80.21). Dilute this with 2 or 2.5 mL of 0.9% preservative free saline to a concentration of either five or four units/0.1-mL dilution. In most instances, use 2-mL dilution as it minimizes diffusion of the solution to neighbouring muscle groups. Upon reconstitution with preservative-free saline, it can be stored at 4°C and be used with no decrease in efficacy for up to 2 weeks.

Technique of mixing

1. Open the bottle of Botox (botulinum toxin A) by removing the cap.
2. The rubber cover is sterile and does not need to be wiped with a spirit swab.

Figure 80.21 Showing Botox vial (100 units) 2 cm^3 of preservative free saline is being injected.

3. 2.5 mL of preservative free saline is drawn up in a 2.5-mL syringe with a size 25-gauge needle with no air bubbles.
4. The syringe containing saline is held vertically and the needle pierces through the rubber bung of the freeze-dried Botox vial. There is no necessity to inject as the negative pressure in the bottle will suck in the saline. The bottle should not be shaken but gently rolled between the palms of the hands to ensure a good, even mix.
5. The mixed Botox solution is now drawn through the 25-gauge needle into insulin syringes. Use either a 30-gauge half-inch or 32-gauge half-inch needles attached to the insulin syringe to inject the Botox.

Injection technique and dosing for various sites

In order to reduce pain, always use ice application to the area concerned for at least 10 minutes and after injection for another 5–10 minutes. Upon injection, it should not be massaged as this will result in rapid diffusion producing undesired side effects.

The number of units to be injected depends on

- The specific region
- Muscle mass (gender dependent)
- Skin thickness (thicker skin in some Asians will require a higher dose)

Table 80.1 illustrates the units used for the various applications in facial rejuvenation.

The following illustrates the various sites for injection:

- Glabella complex (Figure 80.22)
- Forehead horizontal lines (Figure 80.23)
- Crow's feet (Figure 80.24)
- Bunny lines (Figure 80.25)
- Dimpled chin (Figure 80.26)

When injecting into the muscle mass, the injection needle should be perpendicular to the skin and into the muscle. In areas where skin is thin, for example peri-ocular, the injection needle should be in a subcutaneous plane.

Table 80.1 Units used for various applications in facial rejuvenation

Sites	No. of units (average)
Corrugators – glabella complex	Women 20
Procerus – glabella complex	Men 30
Orbiculars oculi – crow's feet	Per side 12–14
Horizontal lines on the forehead	Women 15, men 24
Brow rejuvenation	4 units per side
Masseteric hypertrophy	Women 30, men 35
Bunny lines on the nose	3
Lines along the lateral wall of the nose	4
Poppy chin	Women 5, men 8

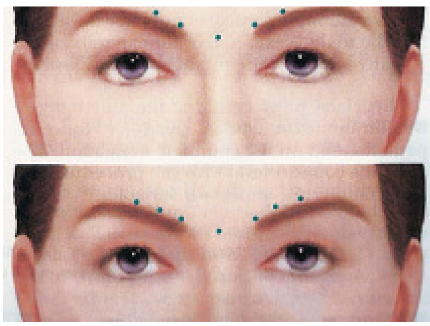


Figure 80.22 The points for injecting Botox in treating the glabella complex.

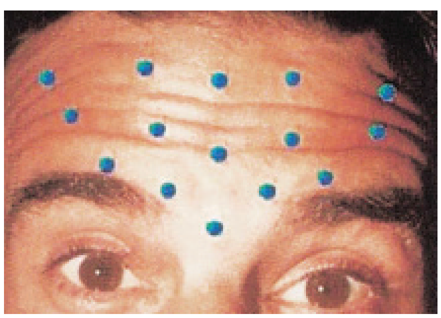


Figure 80.23 The points at which Botox is injected typically for forehead horizontal lines and the glabella complex.

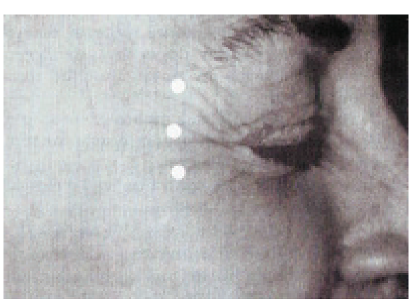


Figure 80.24 The injection sites for crow's feet. It should be a minimum of 1 cm lateral to the orbital bony rim.

Figure 80.25 Sites for injection to rid of bunny lines.

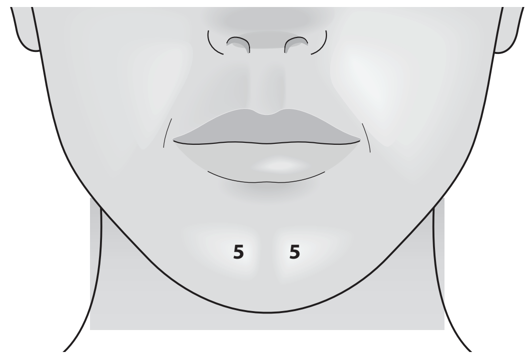


Figure 80.26 Site for injection to treat dimpled chin.

PATIENT SELECTION, COUNSELLING AND INFORMED CONSENT

The initial consultation is critical in understanding the patient's expectations of the treatment if unhappy patients are to be avoided. A medical and drug history is essential. Patients on aspirin, nonsteroidal anti-inflammatory drugs or vitamin E should stop the medications 7–10 days before treatment to avoid bruising. Likewise, anticoagulants should be adjusted appropriately by the treating physician to bring the international normalized ratio (INR) to around two or if there is no contraindication to stop the warfarin at least 72 hours before the procedure.

In the initial examination, document the wrinkles and lines seen in a static position and in a dynamic setting. Most patients would like to know the safety of Botox, particularly if they are having the treatment for the first time. There is adequate evidence to support the fact that botulinum toxin when used in facial areas has long-term safety issues. It is important to discuss known adverse effects reported such as ptosis, headache, pain at injection site, bruising, unexpected results such as brow asymmetry, drooling of saliva and asymmetry at the angle of the mouth. Botulinum toxin A should not be given in the following conditions:

- During lactation
- Inflammatory skin conditions
- Patients with myaesthenia gravis or Eaton–Lambert syndrome

Some of the specific uses at certain anatomic locations are listed below.

Glabellar complex

The musculature responsible for producing the deep furrows in the glabella complex are corrugator supercilii, procerus and depressor supercilii (Figure 80.27). The fibres of ocularis oculi and frontalis interdigitate with the corrugator. The corrugators move the eyebrow medially inwards and depress the brow. Procerus is also a depressor of the medial eyebrow. Orbicularis oculi also depresses the medial eyebrow. Injection sites for the glabellar complex are shown in Figure 80.22. In general, for the glabella complex an average of 20–25 units of Botox at 2-mL dilution is used. Men require a greater dosage (approximately 30–35 units). In oriental women with epicanthal folds, a lower dose is used and the author does not exceed 15 units. Patients are seen at 2 weeks and another 5–10 units reinjected, if necessary. Use four or five units at each injection point depending on the depth of the furrows. Always see these patients at 2 weeks and carry out 'top ups'. If this area has to be retreated, the author waits 4–6 months.

Horizontal lines of the forehead

The hyperactivity of the large vertically oriented frontalis muscle is responsible for the horizontal lines. The frontalis elevates the brow. It is very important while injecting Botox into the frontalis that the needle should be 2 cm above the orbital rim to prevent brow ptosis. Do not inject the horizontal lines at the same sitting as the vertical furrows of the glabellar complex. The author usually defers it by 2 weeks. Inject the first horizontal line and ensure that you are 2 cm above the orbital rim. Three injection sites are generally used on either side of the midline for each line for men and two sites for women. Use a total of approximately 20 units for women and 30 units for men. If brow elevation in a female patient has been discussed as part of the treatment, use 2–4 units into the lateral orbicularis oculi so that the frontalis is unopposed.

Recall all patients after 2 weeks and carry out 'top ups'. One important aspect of injecting Botox into horizontal lines is to assess brow asymmetry at the initial visit and show this to the patient.

Crow's feet

These result from hyperactivity of the orbicularis oculi muscles. Prior to injection of this area, assess for lower eyelid laxity and lid retraction. The orbicularis oculi encircles the eye as a sphincter. In treating crow's feet, an injection is made into the lateral orbital component of the orbicularis oculi. Depending on the lines, typically use three to five injections.

The injection site should be 1.5 cm from the orbital rim. The author would normally use four or five units per site. Recall patients in 2 weeks and top up if necessary. Prior to injection, ice application is used to minimize bruising as the injection is made subcutaneously. Injection should not be carried out for at least 4 weeks following a blepharoplasty or a rhytidectomy or laser assisted in situ keratomileusis (Lasik).

Bunny lines

They are seen on the sides of the nose and result from contraction and hyperactivity of the transverse portion of the nasalis. Into each line no more than two units is necessary and another two units in the midline into the procerus (dilution 2.5 mL).

The use of Botox in the peri-oral area should be avoided and instead fillers used. Dimpled chin is due to hyperactivity of the mentalis muscle. Typically the author uses five units/injection into two sites (usually 10 units in total) and top-up 2 weeks later (Figure 80.26). Platysma bands can also be treated by Botox (see Figure 80.20). They appear as vertical bands. Typically for a vertical band, use five to six injection sites (25–30 units in total) and top up 2 weeks later. One of the complications of injecting into the platysma bands is dysphonia, dysphagia and neck weakness.

(a)

(b)

Figure 80.27 (a) Pre-Botox injection – 40-year-old female. (b) Post-Botox injection (4 months later) – 40-year-old female showing abolition of furrows in glabella complex and brow elevation. Brow plasty done with Botox injection four units on each side.

Top tips

Fillers

- Harvested fat can be stored long term at -20°C for up to 2 years.
- Fat can be reinjected at 6–12 weeks intervals by rapid thawing.
- When fat is stored, it is best saved in labelled 10-mL syringes. The infranatant should be decanted, but the triglyceride layer kept intact.
- While injecting fat, use only blunt needles (a Coleman needle).
- In the first post-operative visit a week later, fat protrusions may exist. Use a Coleman cannula to 'feather' this using a negative suction in a 10-mL Luer-Lock syringe (lipo-sculpturing).
- Fat injected into cheek and the eyelids lasts well.
- Fat injected into the lips disappears rapidly and is not the ideal choice as a filler for the lips.
- Injected fat undergoes fibrosis, progenitor cells differentiate into mature adipocytes.
- It is an excellent adjunctive technique for facial volumetric rejuvenation.

Synthetic fillers

- Give as much information as possible to your patient regarding the filler you propose to use. In particular, discuss all complications and your reasons for recommending the particular fillers.
- Obtain an informed consent.
- Avoid using them in patients taking medications likely to promote bleeding and bruising, e.g. aspirin, plavix, anticoagulants. Stop these medications including supplements, e.g. gingko biloba, for at least 5–7 days before the procedure and do not recommence until after 48 hours.
- Be very atraumatic in your technique.
- Each agent requires a different technique and when you begin, learn from someone who has used the material for some time and attend a course.
- Select your filler according to your wish for a more permanent, semi-permanent or temporary result. If a permanent filler is to be used, over-correction should be avoided. Inject permanent fillers in a much deeper plane. Liquid silicone is notorious in producing fibrosis if injected subcutaneously.
- Apply ice packs for 24–48 hours.
- If swelling is severe, use oral corticosteroids.
- Avoid fillers in patients with autoimmune disorders.
- In general I advise against the use of collagen or collagen containing fillers.
- The safest are hyaluronic acid derivatives of synthetic origin and polyacrylamide gel.
- Inject fillers, when possible, under local anaesthetic block to avoid pain.
- Ask your patient to report immediately if any adverse reaction is noted.

Botulinum toxin type A (Botox)

- Carry out a careful assessment of the wrinkles and lines at rest and in function.
- Understand the patient's desires and if unrealistic do not accept.
- Give a detailed explanation of the underlying problems, your proposed treatment plans, known complications and contact details of the clinic should any complications arises.
- Give precise post-Botox instructions in a written leaflet.
- The patient must understand that the effect of Botox is temporary and further treatments will be necessary.
- It is essential to have an informed consent signed.
- Stop all medications such as vitamin E, aspirin, anticoagulants, supplements, e.g. gingko biloba, at least 7 days before the procedure.
- Apply an ice pack for at least 10 minutes prior to injection and another 5 minutes after injection.
- After injection, the area should not be massaged.
- Carefully inspect the lower eyelids for any lid laxity.
- Do not inject Botox into lactating mothers.
- No injection of Botox should be given into areas where there is skin infection.

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Hair transplantation

N RAVINDRANATHAN and E ANTONIO MANGUBAT

CONTENTS

INTRODUCTION

Modern hair restoration surgery (HRS) has evolved significantly since its original introduction in the United States in 1959. HRS includes many different techniques including hair transplantation (HT), scalp reduction, scalp flaps and tissue expansion. The most common cause of hair loss is androgenic alopecia (AGA), more commonly known as male pattern baldness. Other processes that lead to hair loss are trauma, diseases such as alopecia areata and lichen planopilaris, and iatrogenic causes, most commonly prior surgery.

HRS TECHNIQUES

The modern surgical treatment of AGA was introduced in the United States by Norman Orentreich with the publication of his landmark article hypothesizing his theory of donor dominance. He postulated that autografted hair follicles grew in bald scalp because the hair-bearing donor tissue retained its dominant expression despite being transplanted into a bald scalp. Thus, the modern HT was born.

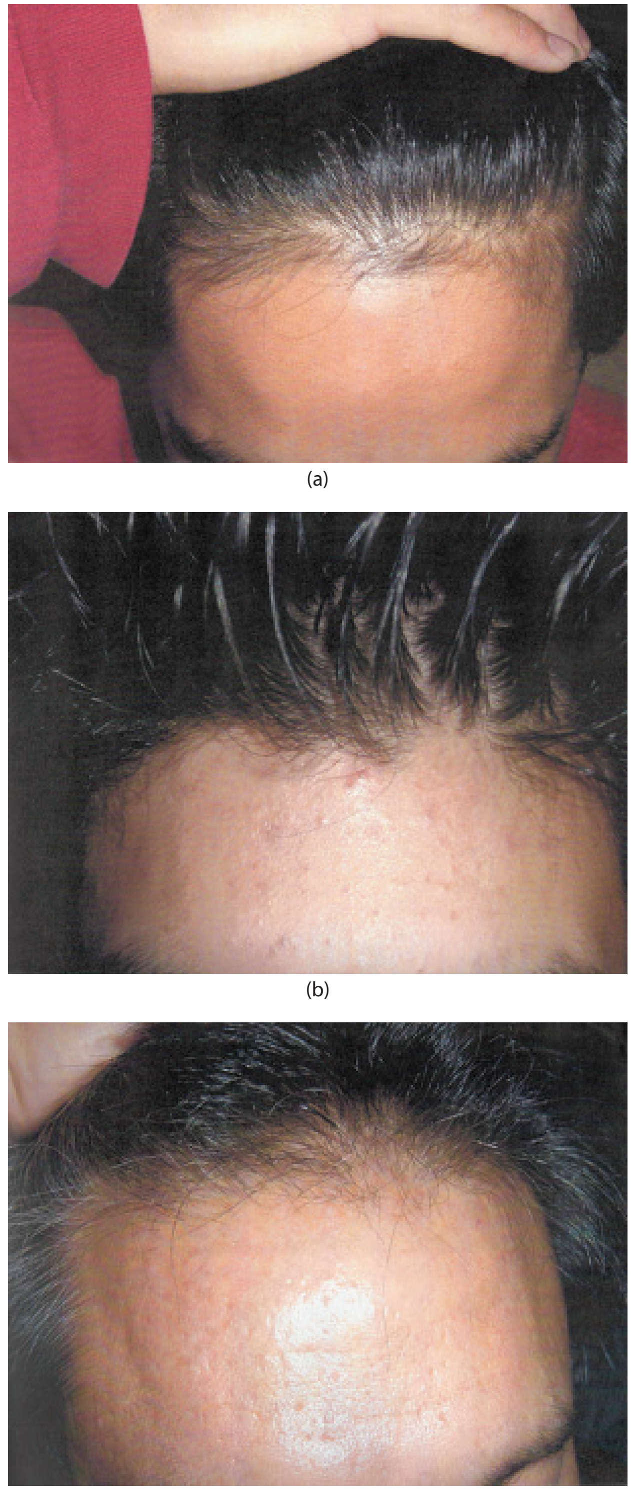
The essence of HT is the movement of hair-bearing donor tissue from the 'permanent' occipital scalp to the balding frontal scalp in the same patient. This is simply rotation of current hair inventory; more hair is not produced, just simply rearranged. Orentreich originally accomplished this by taking 4-mm round punch biopsies of occipital scalp and placing them in the bald frontal scalp. The grafts would take and hair would grow in the previously barren scalp. For most balding men and women, this was a miracle and an answer to their hair loss concerns. For Orentreich's patients at the time, any hair was good hair regardless of its unnatural appearance.

HAIR TRANSPLANTATION

Factors affecting the success of an HT procedure are numerous and must be considered in the treatment of any hair deformity. Natural cosmetic results are highly dependent on these factors, which include the following:

- Extent of hair loss. This determines the amount of work required to cover the defect.
- Age of the patient. Bear in mind that the extent of hair loss increases with age. Young men with AGA will have less hair to transplant and more bald area to cover as they grow older.
- Adequate donor tissue. There must be sufficient donor hair density and tissue to provide enough grafts to cover the hair defect. HT does not produce more hair but rather relocates existing hair on the patient's scalp. Unfortunately for most patients, the more hair they need, the less donor tissue they have.

- Hair colour affects perceived coverage. The darker the colour, the greater the apparent coverage per graft; however, dark hair also tends to create a more unnatural appearance.
- Hair curl increases the apparent volume of hair present in that curly hair covers more area as it bunches up on itself.
- Hair contrast plays an important role in naturalness. The greater the contrast, e.g. black hair on white skin, the more unnatural the appearance. Care must be taken to use the finest single hair grafts in the most exposed area, i.e. the hairline.
- Hair shaft diameter is an important determinant in how much hair is moved in a graft. The thicker the diameter, the more prominent the hair and the more contrast it provides. Thick hair shaft diameters make producing a fine natural hairline challenging.
- Hair direction of the grafted hair must be matched to the existing naturally occurring hair follicles of area being transplanted.
- Hairline considerations. A natural hairline is actually a misnomer. A natural hairline is a zone of fine irregular hairs that create the feathering zone as the bald scalp gradually yields to hair-bearing scalp.
- Ethnic differences are wide and varied and usually can be described as a combination of the earlier-listed characteristics. For example, Asian hair is less dense than Caucasian hair, but the hair shaft diameters are typically thicker. The converse is also true that Caucasians typically have greater density (hair follicles/mm^2) but smaller shaft diameters.



(a) (b) (c)

Figure 81.1 (a) A 17-year-old man with no hair loss. (b) A 15-year-old boy who lacks any vellus hairs but note the strikingly nomadic hairline. (c) The hairline of a 50-year-old man.

HAIRLINE DESIGN

The most important area of challenge to HRS surgeons is the hairline, which is the transition from bald skin to hair-bearing skin. Hairline is actually a misnomer as it is not a line at all. The natural hairline is more of a zone at the bald skin–hair perimeter that exhibits the characteristics of an uneven undulation of the hairs along the border of the bald skin–hairline interface as well as a gradually increasing hair density gradient. Figure 81.1a demonstrates a 17-year-old boy with no hair loss. Note the large numbers of fine vellus hairs present in the anterior border that will eventually be lost as he ages. Figure 81.1b shows a 15-year-old boy who lacks any vellus hairs but note the strikingly nomadic hairline. Figure 81.1c shows the hairline of a 50-year-old man. Note the loss in density in the hairline with a more gradual density gradient. These examples are not transplanted hairlines and they all exhibit an uneven undulating zone of hair.

Also note the important variations in hair direction. The vellus hair gives clues as to the true natural hair direction that the transplant must simulate to achieve a natural result. In general, frontal scalp hairs point forward, parietal scalp hairs point lateral and inferior and occipital scalp hairs orient posteriorly and inferiorly.

When designing a hairline for transplantation, the surgeon must be aware of these subtleties to avoid drawing attention to the transplantation. Most laypeople do not understand what a natural hairline is but they can usually detect an unnatural hairline. The results produced with contemporary techniques go virtually undetected (Figure 81.2a through d). Unfortunately, the old pluggy

results (Figure 81.3) still exist as a constant reminder of our struggle to perfect the technique and of why the laypeople hesitate to seek out a surgical treatment for hair loss until they have exhausted all other possibilities.

FOLLICULAR UNIT TRANSPLANTATION

In the last two decades, the trend has been to transplant very small grafts using one to four hair follicles per graft unit. Now termed 'follicular unit transplantation' (FUT), modern technological advances have increased the number of follicle units transplanted in each session from an average of 1000 up to 3500.

Indications in men

- AGA (hereditary baldness or male pattern hair loss)
- Loss of scalp hair in selected cases following burns and accidents
- To cover surgical scars
  - Moustache creation to camouflage bilateral cleft lip scars
  - Bicoronal scalp scars associated with loss of hair
- Loss of eyebrow hair
  - Alopecia areata
- Lichen planopilaris

The consultation

The process of consultation is an interactive decision for ascertaining the goals of the patient and assessing if these are achievable. The key points are as follows:

- The ascertainment of patient goals. An experienced surgeon must exercise the power of judgement in eliciting a patient's goals. A specific question needs to be asked on what area of hair loss is most bothersome to the patient and understanding the motivating factor for seeking HT. Upon understanding the patient's goals, analyse

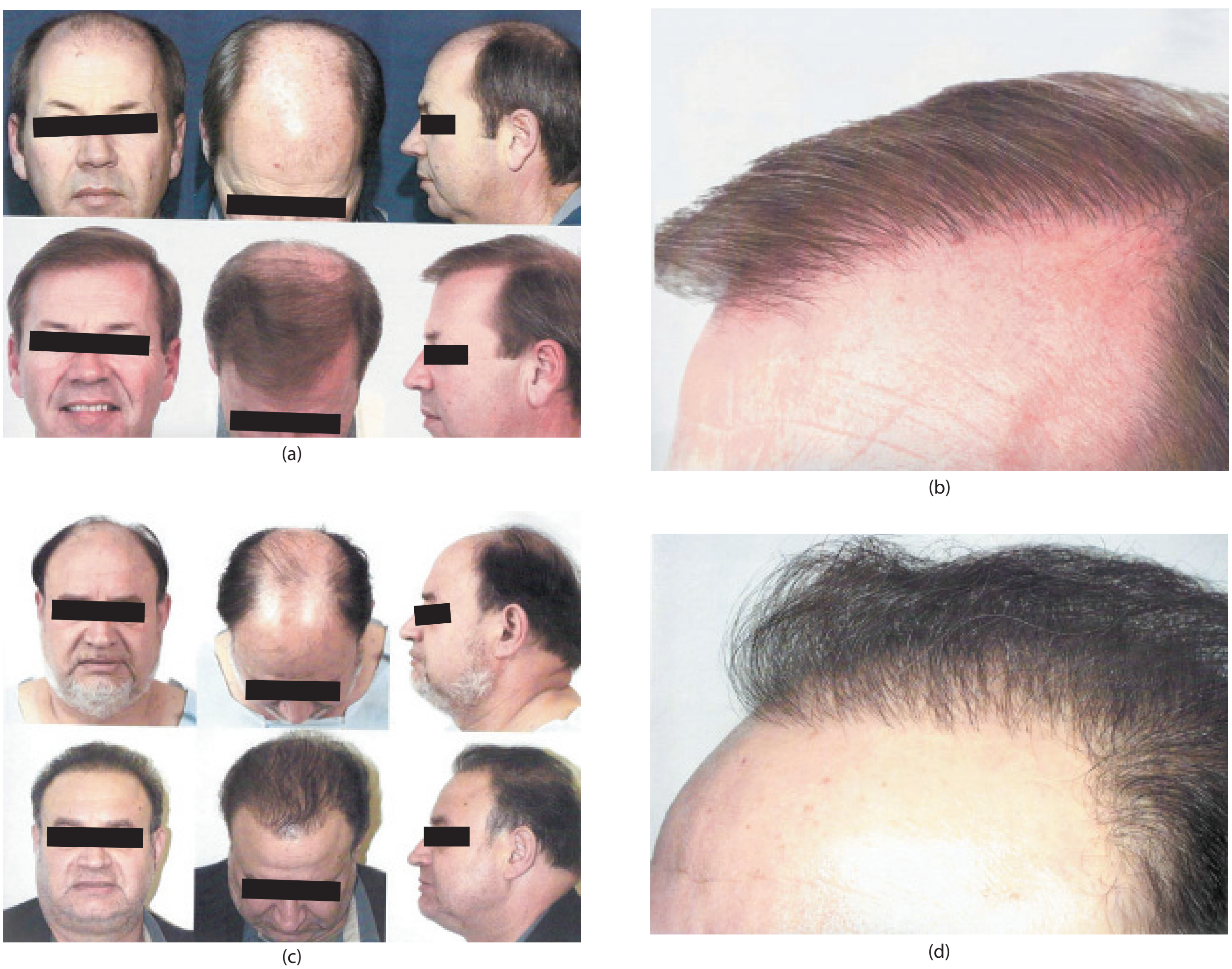


Figure 81.2 (a) Hair transplant. (b) Close-up of transplanted hairline. (c) Hair transplant. (d) Close-up of hair transplant.

Figure 81.3 Unnatural hairline.

if these are achievable or unrealistic. An experienced surgeon would not hesitate to refuse a proportion of patients who seek HT in view of unrealistic goals. It is imperative to recognize a patient who will not be satisfied with the HT procedure. The long-term satisfaction of the patient depends largely on decisions arrived at the initial consultation rather than the technical ability of the surgeon. It is customary for most patients who seek hair transplants to have tried medical treatment, herbal therapies, previous hair transplants but dissatisfied with the result and may have obtained referral from your patients, physicians known to the surgeon or seen photographs in the web page of the surgeon. Hence, when such a patient seeks treatment, it is most important to be honest in revealing what you can achieve and the required process to achieve the goals.

- Explanation regarding the progressive nature of hair loss. Despite transplantation, hair loss may be progressive and at present we are unable to predict the extent of a person's baldness. It must also be made clear that in view of this, the long-term result is unpredictable.
- Requests for transplantation into vertex. Transplantation into the vertex is accompanied by progressive substantial hair loss resulting in an unnatural appearance. However, anterior hairline restoration can be natural and the aim of any practising hair transplant surgeon must be to achieve a natural looking result.
- Hair restoration in a bald patient returns the natural facial appearance and unquestionably restores the central face as the focus of attention. This is an important factor to realize in the initial consultation.
- Transplanted hairline. This is initially permanent. Upon restoring the hairline, there is an appreciable difference in facial appearance. As hair loss is progressive, the created hairline must be acceptable throughout the lifetime. A young person seeking hair transplant may address only the frontotemporal troughs. However, in an older person, it would be an unrealistic expectation if bald in the hairline.
- At the very onset, elicit if the patient is seeking hair restoration only by medical treatment. If the hair loss and associated baldness cannot be restored by medical treatment alone, the surgeon should clearly explain that this would not be possible. If the patient accepts the recommendation of surgical restoration, at this juncture explain the necessity to be treated with supportive adjunctive medical therapy.
- If a surgical option is being planned, a detailed medical and drug history is important. The most pertinent questions to be asked are as follows:
    - Previous bleeding problems.
    - Current hair loss medication.
    - History of drug allergies.
    - Intake of medicines such as aspirin, warfarin and clopidogrel. When possible, these medications should be stopped. It is customary to stop aspirin for 1–2 weeks and clopidogrel 5 days before HT.
    - Intake of dietary supplements, such as ginkgo biloba, vitamin E, garlic and ginseng, increase tendency to bleed. They should be stopped for a week before the procedure.
    - Patients with prosthetic heart valves or prosthetic joints may require standard antibiotic prophylaxis regimes in selected cases as guided by the physician.
- In an HT practice, we highly recommend employment of either a full- or part-time counsellor. Patients often feel more comfortable speaking about the procedure other than to the treating doctor. The counsellor should reinforce the following:
    - Explanation regarding the patient's current hair loss
    - Progressive nature of balding
    - Reiterate the treatment plan
    - Explain the likely complications
- Discussion of limitations. Convey at the very outset that the hair loss is not static and further transplantation may become necessary. Do not give a time frame. A patient who has understood very clearly that balding is progressive would easily accept maintenance transplant sessions at a later stage. Adjunctive medical therapy can be useful in preventing continued hair loss.
- Explain very clearly that in the immediate post-operative period there would be hair loss (post-operative effluvium). It is believed to occur due to local tissue trauma. Vellus hair is the most susceptible although terminal hair can also be affected. Some believe prescribing finasteride immediately after transplantation may modify this loss. However, there are no double-blind studies to support this observation. The surgeon and the counsellor should emphasize that there would be an interval of approximately 6–9 months between the transplantation and the expected result of new hair growth.

- Selection of the appropriate patient. This is governed by (a) degree of baldness, (b) patient expectations, (c) calibre of the hair shaft, (d) donor hair availability and its quality and (e) age of patient. In general, it is best to avoid young patients in the age group of 20–25 years. Young men in this age group usually consult to explore transplantation to restore the areas of baldness due to frontotemporal recession (Norwood stages 1 and 2). In these patients, if facial framing is intact, there is no benefit in transplantation. Calibre of the hair can vary from fine to coarse hair. The larger the diameter, the better the result. Patients with fine hair have a diameter of less than 60 µm. Fine hair covers less surface area and hence yields poor results. Some would refuse to carry out transplantation in these individuals.
- Donor hair quality determines surgical outcome. In general, men require 40 follicular units per cm^2 in the occiput for successful transplants. In general, Caucasians have more follicular unit counts than Asians. The ultimate determining factor for the success of HT depends on the patient's expectations. If the patient's expectations are unrealistic and, through the process of consultation and use of the counsellor, cannot be modified, the patient should not be accepted for transplantation. For patients with fine hair, a limited donor site source cannot provide transplanted hair of satisfactory density. In such patients, time spent in detailed explanation is very worthwhile. Patients who seek vertex transplantation should be warned of significant future loss. Likewise, patients who request transplantation from vertex to frontal scalp should be discouraged.

Thereafter, the main steps are the following:

- Establishment of hairline. This is often an area for misunderstanding. An unrealistic request to make the hairline too low which would be unnatural must be pointed out clearly in the discussion. A good method to adopt is to seat the patient in front of a mirror and draw the proposed hairline on their skin.
- Assessment of the state of baldness and assigning the patient to the Norwood classification (Figure 81.4). At this stage, bring it to the attention of the patient that baldness is progressive.
- Once the discussions have been completed and the decision for transplantation has been made, discuss other surgical options such as scalp reduction and the reasons why as a procedure this is no longer popular.
- No consultation is complete without a discussion of risks and complications and obtaining informed consent (Table 81.1).
- Photographs – the following views are required:
  - Frontal view
  - Lateral views (right and left)
  - Vertex view
  - Posterior view
  - Hairline close up

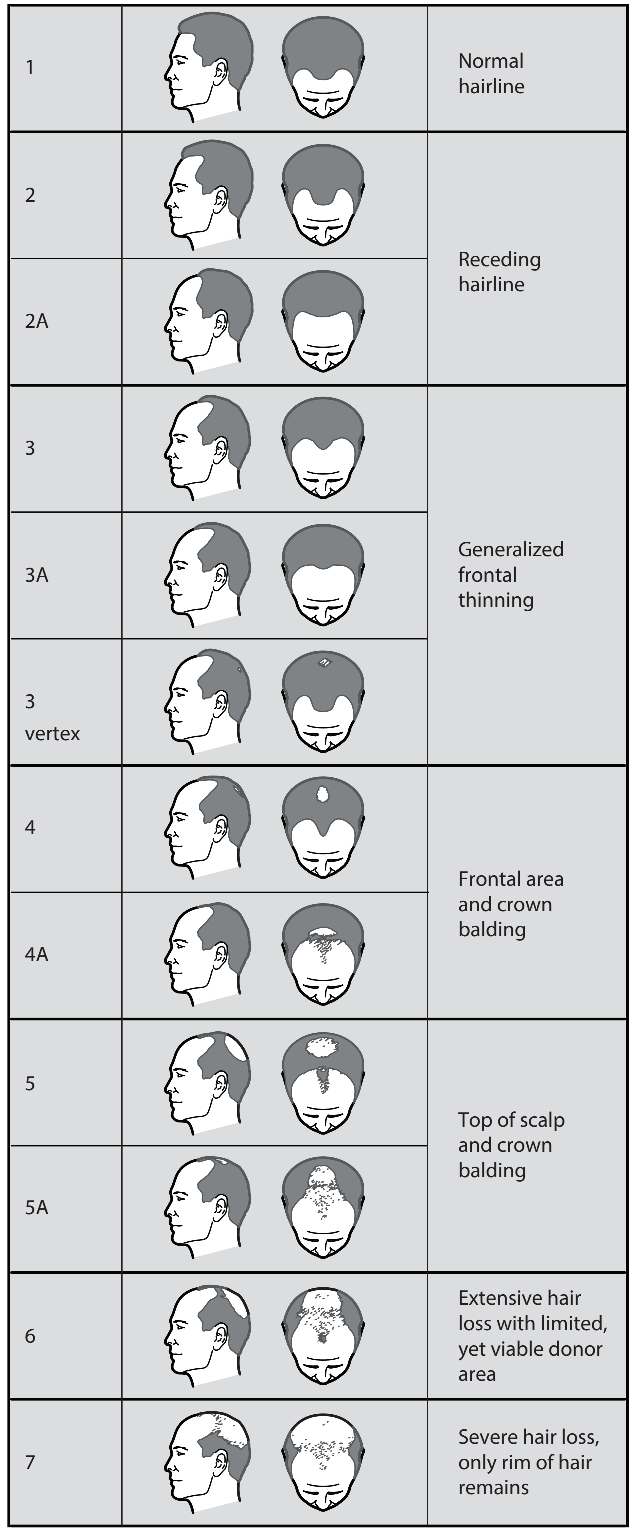


Figure 81.4 Hair loss classifications (Norwood classification).

It is important for the transplant surgeon to be aware of medico-legal issues. This surgery is not dealing with 'life-and-death issues' and therefore litigation is more common.

Table 81.1 Consent for hair transplantation

The procedure of hair transplantation has been explained to me. The area to be transplanted and the areas of anticipated coverage have been discussed and mutually agreed upon. I am aware that hair transplantation is to be completed over several sessions and a final appraisal of the results cannot be adequately done until the procedure is complete.
I am aware of the following complications associated with hair transplantation:
1. Pain, tingling, 'pins and needles' sensation
2. Bleeding, crusting and scab formation
3. Swelling around the forehead and occasionally the tissue around the donor area, nose, cheeks and eyes
4. Numbness or loss of sensation on the scalp
5. Infection
6. Dizziness or fainting (either from bleeding, medications or anxiety)
7. Allergic reaction to medications
8. Scar formation (depressions or bumps)
9. Insufficient growth of hair requiring more than anticipated transplantation procedures to provide expected results
10. Irregular, uneven or delayed hair growth. Many transplanted hairs will shed after each session. Generally, 3–4 months after the transplantation new hair growth begins. The new hair will sometimes grow in with a variation in texture (coarser, finer, darker or lighter) until it normalizes
I give permission to perform the hair transplantation on me and agree to follow-up as directed by the hair transplant surgeon.

Principles of HT

The following principles and guidelines must be adhered to in achieving success in HT surgery.

Donor site

- Harvesting hair from the occiput should be from within a margin of clearance of about 2.5 cm from the lateral and inferior fringes of the occipital hairline (Figure 81.5). Avoid harvesting above and medial to the mastoid area.
- The lateral limit of harvesting should not extend beyond a vertical line extending into the scalp from the pre-auricular line. Harvesting performed anterior to this line can result in visible scar formation. The upper limit of the donor site is 5 cm from the uppermost point of the external ear. The lateral limits are the vertical line of the pre-auricular crease extended vertically into the scalp. Where there is paucity of the donor area, the temporoparietal areas can be considered (Figure 81.6).
- The donor tissue can be harvested using a multi-bladed knife or as a single ellipse (Figure 81.7). The multi-bladed knife can have between two and four blades. If harvesting is carried out as a single ellipse, a size 10 scalpel blade (Bard-Parker) is utilized (Figure 81.8).

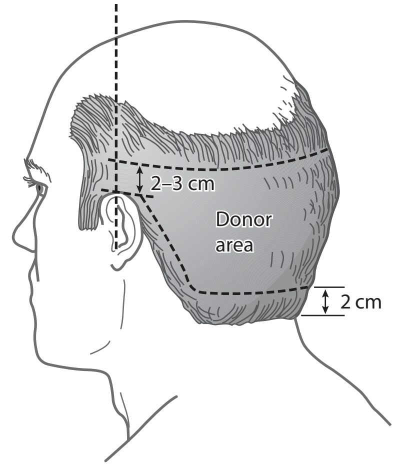


Figure 81.5 Donor area will be 2.5 cm below superior edge of fringe border and 2 cm above inferior occipital fringe.

Figure 81.6 Donor area.

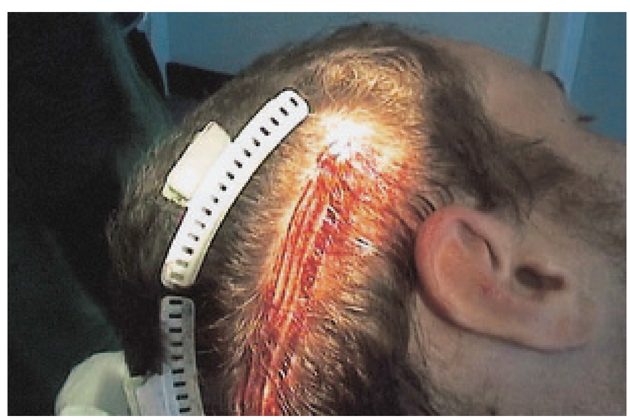


Figure 81.7 Donor site – multiple strips being harvested using multi-bladed knife.

- The incision lines should be parallel to the orientation of the hair follicles to avoid transection and parallel to the lines of minimum tension (Figure 81.9). Use local anaesthesia in the strength of 1% lignocaine with 1:100,000 epinephrine (adrenaline) when using the tumescent technique. If using a multi-blade knife to harvest multiple strips, use the tumescent technique to achieve tissue turgor. Subsequently, 100 mL normal saline is injected into the donor site for tumescence to build up the turgor pressure.

For harvesting the donor tissue as a single ellipse, use 2% lignocaine with 1:80,000 epinephrine (adrenaline) up to three vials or 1% lignocaine with 1:100,000 epinephrine (adrenaline) and inject up to a maximum of 15 ml.

If the tumescence technique is used, use 100 ml of cold normal saline solution for harvesting a strip 12-cm long and 1-cm wide. Debate continues as to whether tumescence is essential. However, if tumescence is used, multistrip harvesting is easier. If a single strip is to be harvested utilizing a single blade, it is not necessary to inject tumescent solution. If a tumescent solution is to be injected, it must be done slowly, 2 ml per time.

Figure 81.8 An elliptical strip being harvested from occipitoparietal donor site.

Figure 81.9 An elliptical strip after incision ready for excision.

Positioning of patient during the procedure

There are two options:

Option 1: Patient is placed in prone position with the head down on a headrest for harvesting of the donor graft and once this is completed, the patient sits on a comfortable dental chair in a partially reclined position.

Option 2: The patient sits on a reclined dental chair for the entire procedure.

TECHNIQUES OF HARVESTING THE GRAFTS

Multi-blade technique

A multi-blade scalpel is utilized. The type most commonly used is an Arnold multi-blade knife. According to the number of strips required, the number of blades used varies. For each 2-mm strip, one blade is required. The width between each blade can be adjusted by utilizing the appropriate spacer. Spacers come as 1.25, 1.5 or 2 mm (Figure 81.10). Multi-blade harvesting increases follicular transection. Most prefer a single-blade technique. However, the disadvantage is that the strips have to be cut and prepared from the main elliptical harvest and is more time-consuming. However, the transection rate is less.

Technique of harvesting

- The hair in the designated donor area is trimmed. The incision is made along the lines marked parallel to the hair follicles and deepened through below the follicular bases but above the deep vasculature. It is necessary to maintain a small amount of subcutaneous fat at the base of the hair follicles. While the strip is being elevated, the surgeon should be careful to ensure that the depth is correct, follicles are not being transected and

Figure 81.10 Multi-bladed knife for harvesting multistrips and single blade for harvesting an ellipse.

there is subcutaneous fat at the base of follicles. Use a 4× magnifier when harvesting (Figure 81.11). Use of cautery must be avoided and hence only pressure is applied to control bleeding. During closure, carry out minimal undermining (Figure 81.12). Apply tension clamps across the edges to approximate and use a few deep dermal sutures of 2.0 polydioxanone (PDS) at least 5 mm away from the wound edges (Figure 81.13). The preferred choice for skin closure is staples as it gives the best scar. However, if using a suture, use a continuous 4/0 nylon suture. Remove the staples or sutures on the 10th day. See the patient on the following day and apply hair gel, wash the hair and inspect the wound to ensure that there is no blood collection.

- The preparation of grafts from the harvested multi-blade strip or ellipse (Figure 81.14):
  - Once the graft has been harvested, either as an ellipse or as a multi-strip, it should be placed in cold saline.
  - Hair technologists working on a well-lit bench and wearing magnifiers start to prepare the micro- or mini-grafts (2–4 follicles). If single FUT has been envisaged, microscopes are used for dissection of follicular units.
  - The strips or sectioned ellipses are placed on a spatula (Figure 81.15a) and using a Personna blade size 10, the hair technologist will start sectioning them carefully leaving some subcutaneous fat below the follicles as either mini- or micro-grafts (Figure 81.15b). When prepared, the grafts must be placed in a separate dish with cold saline and they should be placed into the recipient sites within 4 hours to give maximum viability of the grafts. During the preparation, the surgeon should oversee the team preparing the grafts to ensure there is no transection of the follicles and there is atraumatic tissue handling. At the commencement of the procedure, a calculation would have been done to estimate the number of mini- and micro-grafts needed for the planned restoration.

Figure 81.11 Multi-strip harvesting.

Figure 81.12 Minimal undermining of the donor site prior to closure.

Figure 81.13 Donor site being closed with continuous suture.

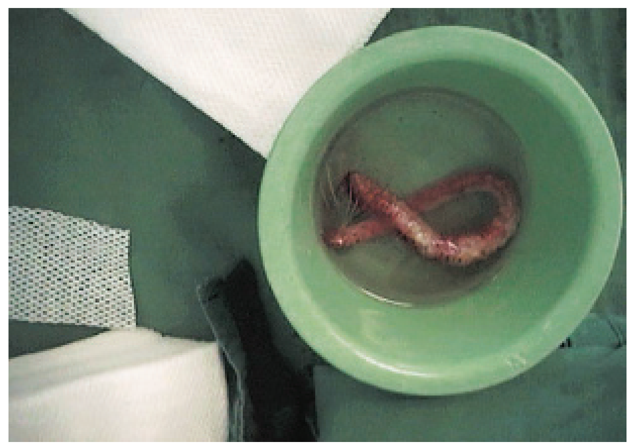
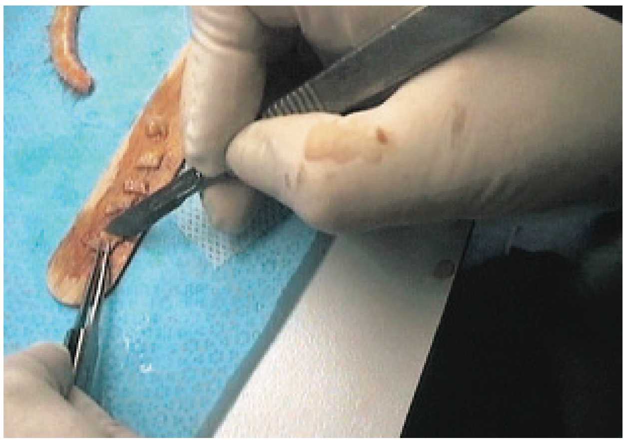


Figure 81.14 Harvested ellipse in cold saline.

(a)



(b)

Figure 81.15 (a) Harvested ellipse cut into a strip. (b) Strips being cut into further smaller strips on a spatula.

- Techniques of recipient site preparation and graft insertion are as follows:
  - Local anaesthesia is administered as a nerve block or ring block with 1 or 2% lignocaine containing 1:100,000 epinephrine. If recipient sites are to be created in the frontal hairline, bilateral supraorbital nerve blocks would be adequate. Similarly, if posterior scalp is the recipient area, occipital ring block can be used.
  - When anaesthesia is established, the recipient sites are created as follows: for single graft use 19G needle (Figure 81.16); for mini-grafts use 15C blade (Figure 81.17).

Slits are made as single-stab incisions and can be made in large numbers. Some use 19G Nokor needles. With each slit there may be brisk bleeding. Usually it stops after the application of pressure for a few minutes with gauze. Sometimes, dilators are necessary to facilitate closer placement of grafts. However, dilators do take more time. Nevertheless, it is an important surgical tool in the armamentarium of a hair transplant surgeon.

Insertion of grafts at the recipient site is carried out using jewellers' forceps (Figure 81.18). Use the finer

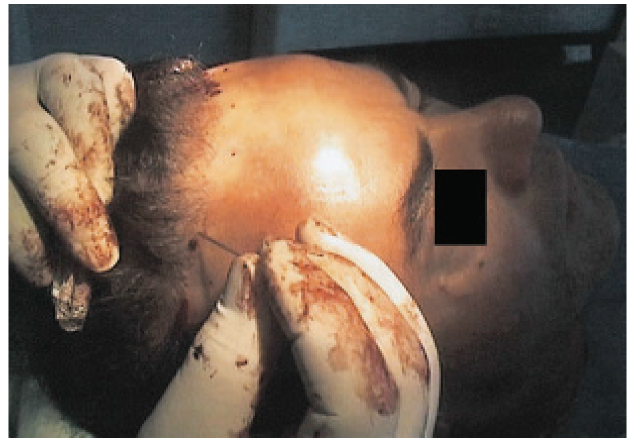


Figure 81.16 Recipient site being created for restoring hairline.

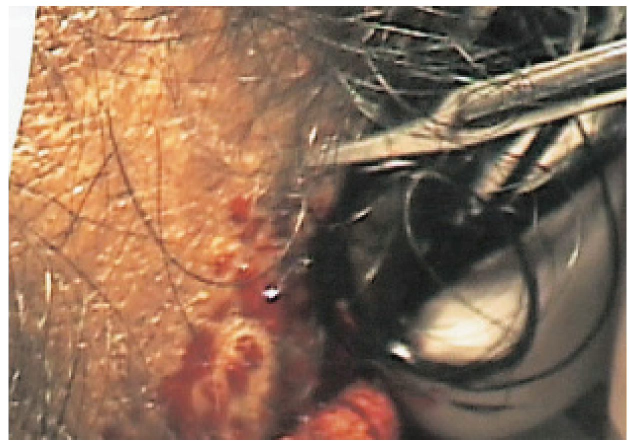


Figure 81.17 Making slits using 15 blade.

Figure 81.18 Curve and straight jewellers' forceps.

version of jewellers' forceps. It is only with considerable patience and effort that the skill of graft placement is mastered. If the grafts are placed too close, adjacent grafts will 'pop out'. This can be controlled by gentle pressure with moist gauze or a graft stick. Regular spraying with saline is done to keep the grafts moist.

Creation of hairlines

When hairline restoration has been planned, in deciding on the hairline, the rule of thirds of the face is followed. The lower third, middle third and upper third of the face are in equal proportions. It is most important NOT to place the hairline too low. The line is usually 8–10 cm above the glabella (Figure 81.19). In patients suffering from severe hair loss, the hairline can be raised higher by 1–2 cm. However, in some patients the line is elevated higher by 1–2 cm, creating a 'widow's peak' (Figure 81.20) giving a camouflaging effect to create a lower hairline.

The aim of hairline restoration is to create a most natural hairline which cannot be detected. The hairline consists of an anterior portion (transition zone) and a posterior portion (defined zone) (Figure 81.21). The transition zone is usually 0.5–1 cm and is irregular. Variation of hair density in this zone is normal (Figure 81.22). In this zone (0.5–1 cm), only single-hair follicular units or micro-grafts must be used to ensure the result appears natural.

The defined zone is usually 2–3 cm in width and should have a higher density of hair. In this zone, mini-grafts containing two to four follicles or two to three follicular units are placed (Figure 81.23).

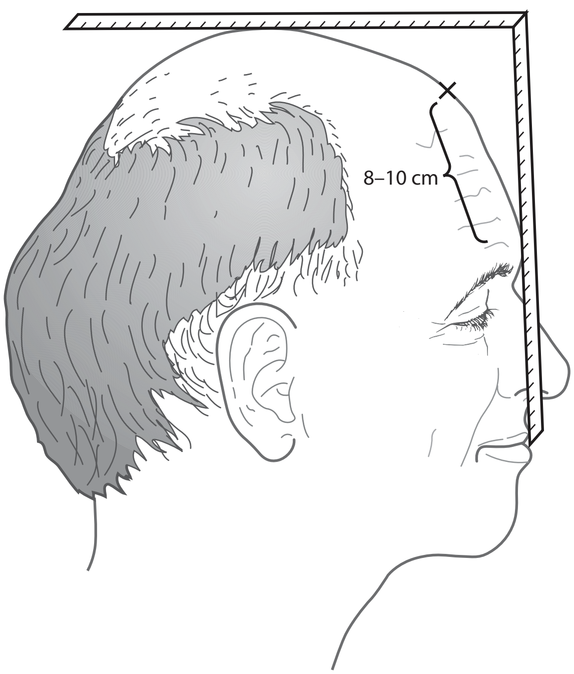


Figure 81.19 Proper placement of the anterior border of the hairline. Common guidelines for locating the anterior border of the hairline include (1) four finger-breadths above the glabella, (2) 8–10 cm above the glabella and (3) the point where the horizontal plane of the scalp meets the vertical plane of the face.

Figure 81.20 Creating a 'widow's peak'.

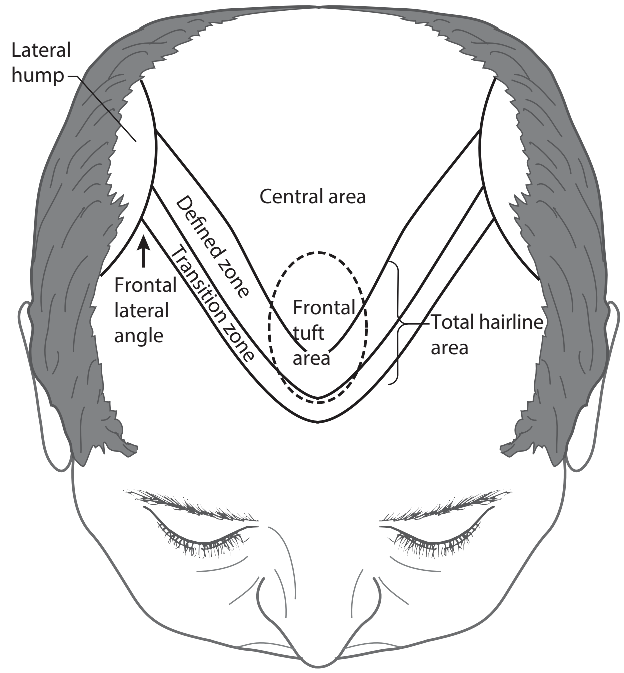


Figure 81.21 Hairline zones: The hairline consisting of two zones: the anterior portion (transition zone) and the posterior portion (defined zone). The transition zone (TZ) should be soft and irregular, and the defined zone (DZ) should be more defined and dense. Both these zones are important to the overall appearance of the hairline.

Creating the lateral border of the hairline and the frontotemporal angle

In all men, the frontal hairline meets the temporal hairline at the frontotemporal angle (Figure 81.24a through c). The angle at its union between the frontal and the temporal line is called the apex (Figure 81.25).

- Do not create this angle too low.
- Do not blunt this angle.

Figure 81.22 Note the hair between the dotted line and the solid line denotes transition zone. The solid line demarcates posteriorly the 'defined zone'. Variation of hair density in transition zone is normal.

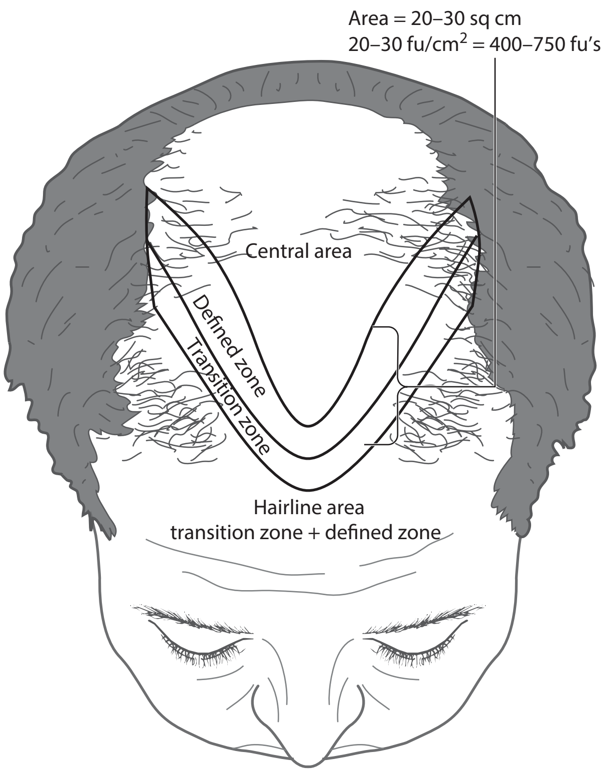


Figure 81.23 Estimated area of the hairline area: the total hairline area is the combination of the TZ the DZ. The average size of the total hairline area ranges from 20 to 30 cm^2. At 25–30 fu/cm^2, it takes about 600–750 follicular units for this area.

- It must appear as natural as possible.
- In achieving this point, draw a line from the lateral epicanthus to where it meets the existing temporal hair.
- The hairline should ideally be parallel or slope upwards.

Figure 81.26 illustrates the placement of frontotemporal angle in severe hair loss.

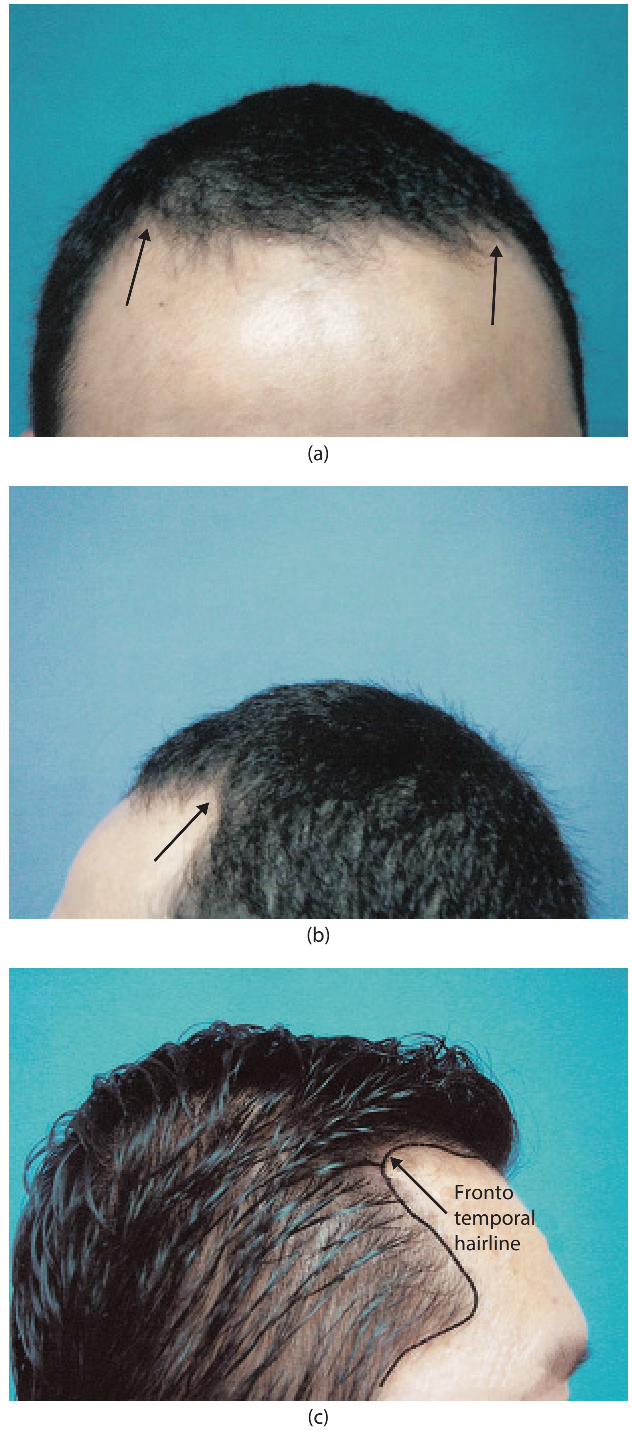


Figure 81.24 (a) Frontotemporal angle. (b) Frontotemporal angle. (c) The frontotemporal hairline in a 24-year-old Asian male.

Summary of creating hairlines

- Mark the anterior border of the hairline, the transition zone and the defined zone.
- Mark the frontotemporal angle.
- Draw the widow's peak if it has been planned.

If no hairline restoration was planned

- Mark out the area of baldness over the occiput or vertex. Draw the intended lines along which the mini-grafts are to be placed (four to five hair follicles).
- Transplant in each row, placing the follicles at least 2 mm apart and 1 mm between each row. If the follicles are placed too close during the placement, the hair follicles will 'pop out'.
- Preparing the recipient sites:
    - For restoring the anterior and temporal hairline, supraorbital and supratrochlear nerve blocks are given using 2% lignocaine with 1:80,000 epinephrine (adrenaline) in a dental syringe containing 2.2 mL cartridges. Usually, 4–5 ml would suffice and anaesthesia can be obtained up to mid scalp.
    - For posterior occipital area, occipital ring block is given.
    - For eyebrow restoration, supraorbital block is given.
    - For moustache creation, bilateral infra-orbital nerve block is given.

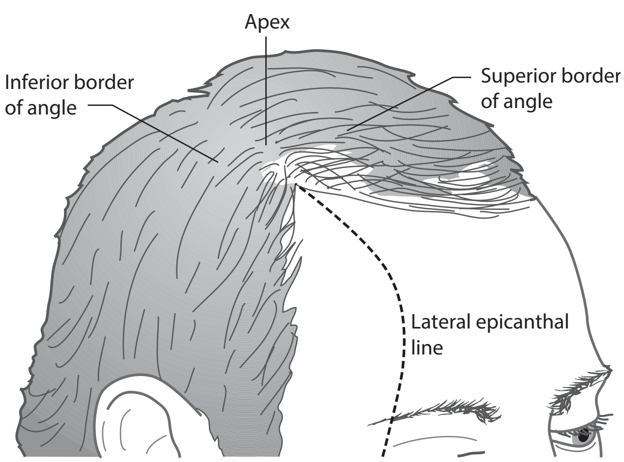


Figure 81.25 Placement of frontotemporal hairline when there is moderate hair loss.

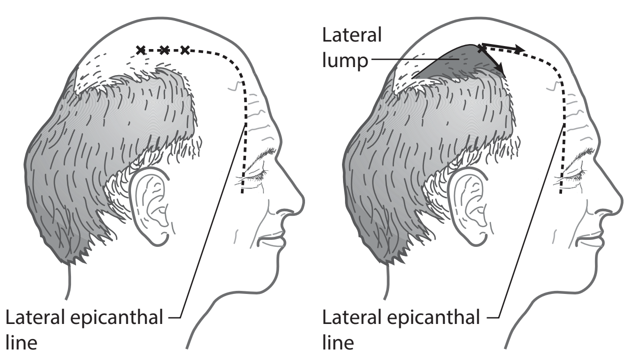


Figure 81.26 Placement of frontotemporal hairline in severe hair loss.

Important notes

- If oral or intravenous sedation is used, continuous oxygen saturation and blood pressure monitoring is mandatory. The most preferred sedative agent is midazolam.
- Prior to the administration of local anaesthesia in an anxious patient, conscious sedation can be used (relative analgesia using nitrous oxide and oxygen combination).
- The most preferred local anaesthetic agent is lignocaine. Some prefer bupivacaine. Bupivacaine is four times more potent than lignocaine. Therefore, 0.25% bupivacaine would be equivalent to 1% lignocaine. It also has a longer duration of action. The greatest danger of using bupivacaine is its property to induce arrhythmia resulting in ventricular tachycardia resistant to treatment.
    - The maximum recommended dose for lignocaine with epinephrine is 7 mg/kg or 0.7 mL/kg of 1% lignocaine. One per cent lignocaine has 10 mg/mL.
    - For an average 70 kg man, the maximum dose would be 50 mL of 1% lignocaine with epinephrine.
    - The maximum recommended dose for 0.25% bupivacaine with 1:100,000 epinephrine is 90 mL or 225 mg.

Giving detailed information and obtaining informed consent

- After HT, the hair is shed within 3–4 weeks. New hair growth will only be seen after 12 weeks and should grow at approximately 1 cm per month. After the transplantation procedure, there may be a temporary increase in natural hair loss but this will regrow within 3–6 months.
- Every hair follicle has a life cycle. Therefore, when transplanted into a new site it will produce hairs which are of a more permanent nature.
- The newly transplanted hair will grow, but with time it will become thin and undergo greying.
- Harvesting of donor hair will not damage the remaining hair.
- Information regarding creation of the frontal hairline and temporal hairline should be given. Ideally, they should be drawn and the consensus obtained and, if agreement is reached, photos should be taken. Personal preference of the patient is an important consideration.
- Advise to stop supplements such as ginkgo biloba and vitamin E 7 days before surgery. Aspirin should be stopped 5 days before the surgery. Alcohol should be forbidden for 24 hours before the surgery.
- An approximate estimate of time to be taken for the procedure should be given. The patient should be accompanied by another person and arrangements should be made to stay for at least 2 hours after the procedure is completed.

- There will be a bandage applied over the forehead to reduce oedema if a frontal hairline has been created. The patient is instructed to wear a theatre cap loosely if required. No shower is to be taken for 24 hours after the first review.
- Instructions regarding pain at the donor site and recipient site should be given. Before leaving the surgical suite, analgesics should be prescribed. The patient should be instructed to sleep on their side. To avoid post-operative oedema, steroids are prescribed at the commencement of the transplantation and continued 8 hourly for 3–5 days. Instructions are also given to take the analgesics regularly with antacids to avoid gastric irritation by the steroids and the analgesics.
- Generally, there is only a faint scar at the donor site.

Likely post-operative complications are as follows:

- Bruising around the forehead and eyelids usually on the third day, which may last up to a week.
- Scalp may ooze from the donor and recipient sites for 24 hours.
- The scalp may be numb.
- There may be headaches for 24–48 hours.
- It is unusual to develop infection.
- Recommend to be off work for 2–3 days if necessary. No active sports should be undertaken for 1 week.

Adjunctive medical therapy in HT

Currently, the US Food and Drug Administration–approved agents that promote hair regrowth are as follows:

- Topical minoxidil solution which comes in strength 2% for women and 5% for men. Women may use 5% minoxidil; however, it has been associated with greater side effects, most notably scalp irritation and increased growth of facial hair.
- Oral finasteride tablets (1 mg daily) for men only.

These two agents will increase hair density, spread of regrowth of transplanted follicles and slow or stop hair loss in areas of active alopecia.

Hair growth is a dynamic process which consists of repeated cycles of active growth (anagen 2–6 years), involution (catagen 2–3 weeks) and rest (telogen 2–3 months). Approximately 90% of all scalp follicles are in the anagen phase. Androgenic hair loss in male and female pattern hair loss is induced by androgens in genetically susceptible hair follicles. Under the influence of dihydrotestosterone, the hair follicles shrink in size and the anagen phase becomes shorter.

The majority of hair transplant surgeons recommend the use of minoxidil and finasteride after the initial consultation for hair loss. These two medications have a synergistic effect. However, when finasteride is given, patients must be warned that there may be side effects during treatment, such as loss of libido, ejaculation disorders and erectile dysfunction. These effects are reversible and affect 2% of men. It usually takes 3–4 months to see demonstrable effects with minoxidil treatment.

The advantages of using minoxidil prior to surgery are as follows:

- Increased number of hairs in anagen phase.
- Increased hair density and hair weight.
- Decreased post-surgical telogen shedding.
- The primary benefit of using minoxidil is within and surrounding the areas of hair loss.
- In the donor area, they may transform telogen follicles into the anagen phase and thereby these grafts would be more visible during the transplantation.

The benefits of using minoxidil after transplantation are as follows:

- Increase in number of hairs in the anagen phase.
- Promotion of growth in the transplanted follicles and surrounding areas, reduction of post-surgical ‘shock’ and telogen effluvium. It also enhances the diameter of the hair shaft, increases hair density and thereby enhances the result. In particular, the following two categories of patients require minoxidil after transplantation:
  - Young male patients with diffuse hair thinning.
  - Female patients with diffuse hair thinning.

Minoxidil should be stopped 5 days prior to transplantation as it may cause increased intra-operative bleeding and it can sometimes cause scalp irritation. After transplantation, minoxidil is restarted 5–14 days after surgery to avoid damage to the transplanted hair follicles. This delay also allows time for the healing of the epithelium. Finasteride, however, can be continued until the day of the surgery and continued immediately after surgery.

Use minoxidil 5% as greater density has been noted than when 2% is used. There is uniform consensus among most hair transplant surgeons to use finasteride and minoxidil pre-operatively and post-operatively in men and minoxidil in women. There is now emerging new evidence that finasteride can also be used in female patients.

Post-operative instructions

- Preferred option – use GraftCyte (ProCyte, Montgomeryville, Pennsylvania) for the first 48 hours as a spray over the grafted sites to prevent crusting.
- Patient is seen 24 hours later and the forehead bandage is removed and a hair wash given.
- Daily hair wash is permitted, but no scrubbing of the scalp is allowed.
- Staples over the donor site are removed on the 10th to 12th day (Table 81.2).

Table 81.2 Post-operative instructions for hair transplant

1.	Do not take any medications (other than prescribed), vitamin E or alcohol for 48 hours after hair transplant.
2.	No dental work 72 hours following surgery.
3.	If at any time should any graft begin to bleed or pull out, simply apply direct pressure to the site for a minimum of 15 minutes. If that does not stop the bleeding, continue to apply pressure and immediately call the hair transplant surgeon.
4.	You will come back to the office in approximately 10 days to have your staples removed.

COMPLICATIONS

Peri-operative complications and side effects are uncommon but may include

- Post-operative oedema over the frontal and peri-orbital region
- Haemorrhage from recipient sites
- Post-operative haematoma at donor site
- After 48 hours, itchiness of the scalp
- Discrepancy between recipient slit size and donor grafts resulting in dropping out of the grafts
- Stretching of the donor site scar
- Poor growth – grafts were not stored as desired in saline and the follicles were dehydrated
- Overly dense packing of grafts resulting in ischaemia and poor growth
- Wound infection

Guidelines for deciding the width and length of donor strip to harvest

1. Make a decision of how many grafts are required, e.g. 1450.
2. Measure the circumference of the back of the head, e.g. 22 cm.

One graft per millimetre length is the rule of thumb. Therefore, in a 22–cm-long strip, 220 grafts can be obtained. Hence, to harvest 1450 grafts, six strips would be required. If a 1.75- and 1.25-mm spacer is used in a multi-bladed knife, you could accordingly obtain micro- and mini-grafts.

Recipient sites

- Proper depth control in site creation is critical (Figure 81.27).
- If the sites are too deep, damage is done to the deeper vascular plexus. Likewise, if the sites are too shallow, graft loss can occur. If the site created is too small, excessive manipulation is required to implant the graft and this would cause damaging pressure on the graft.
- Patience and flexibility in preparation of recipient sites is the key for success. Sometimes, during recipient site creation, bleeding occurs with the slightest manipulation and the adjacent grafts pop up with each new graft insertion. Patience is the virtue. Do not rush the creation of recipient sites. Depth control, angulation and direction of the grafts govern success in a transplant procedure (Figures 81.28 through 81.30).

Figure 81.27 Recipient sites after creation.

Figure 81.28 Grafts in sites after placement into slits.

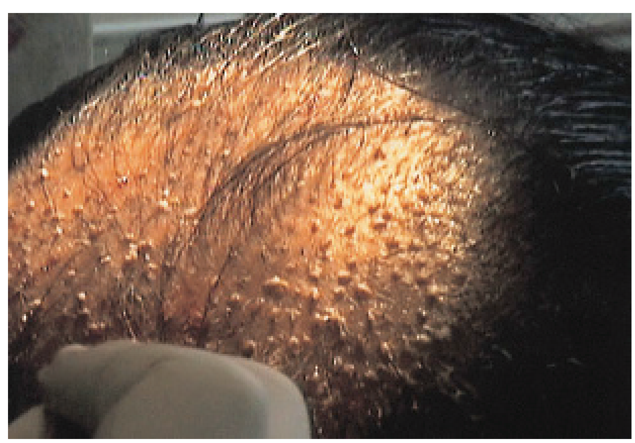


Figure 81.29 Grafts in place in the recipient sites.

Figure 81.30 Grafts in place at the recipient sites.

Figure 81.31 Pre-operative photo for restoration of anterior hairline and anterior scalp.

Figure 81.32 Post-operative photo.

HT in Asians

The following are key facts to be taken into consideration for hair transplant in Asians:

- Usually hair density is lower when compared to Caucasians. The hair is coarse and straight. Hair is darker.
- Asians have a much greater tendency to form hypertrophic scars and keloids. Hence, scalp reduction is a poor option. Likewise, donor site scars may also become hypertrophic. At the earliest detection, intradermal steroids should be injected.
- Asians like to have a low hairline and this request should be resisted and the hairline should only be chosen according to facial proportions and what is most natural.
- Figure 81.31 illustrates a pre-operative view of an anterior hairline in an Asian patient. Figure 81.32 illustrates the hairline after restoration with micro- and mini-grafts.

Top tips

- Harvesting of grafts (donor site – occipital scalp):
    - Maximum length 25 cm and width 10 mm.
    - If a multi-bladed knife is used, spacers between the blades come as 2 or 1 mm. If a previous scar is incorporated into the graft, a 4-mm spacer is used so that in such cases two strips can be obtained. The hair follicles can be dissected from these two strips. To harvest the follicles from these strips, the author uses the 15 blade for monografts and a Personna blade size 10 in the multi-bladed knife between the spacers.
    - If the donor graft is to be harvested as a single ellipse, a conventional scalpel is used with a size 10 blade. Prior to harvesting, trim the hair to a plane where you can just see the hair direction as you would alter the direction of the scalpel with the direction of the hair follicles. From the harvested strip, small strips are made by slicing into small pieces. From each small piece, one, two and three hair grafts are dissected either with or without the use of a 10× stereoscopic microscope. Each follicular unit may have three hairs, two hairs or one hair. Close the donor site as a single layer with staples as this gives the best scar.
    - At no time should the harvested hair follicles be allowed to dehydrate. The grafts must be kept moist throughout the procedure. The best solution in use is either cold Ringer's lactate or cold saline.
    - Warning: while preparing the grafts, DO NOT cause damage to the pilosebaceous unit and transection to the follicles.
- Creating recipient sites in the bald areas or areas to be transplanted:
    - For micro-grafts – 19G needle
    - For mini-grafts – 15C blade

Good rules:

- Aim for 30–25 grafts/cm^2.
- Place the grafts 3 mm apart laterally and 1 mm apart posteriorly.

SUGGESTED READINGS

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82

Brow lift and facelift, including endoscopic surgery

TIRBOD FATTAHI

CONTENTS

INTRODUCTION

Brow lifts and facelifts are commonly performed aesthetic procedures of the facial region. Hallmarks of the ageing process include descent of the brows, redundant tissue in the upper lids, rounding of the lower lids, ptosis of the midface and the superficial musculoaponeurotic system (SMAS), fullness of the nasolabial fold, loss of the jawline, dermatochalasia of the facial region, formation of jowls, platysmal redundancy and submental fullness. Goals of any facial aesthetic surgery must include repositioning of ptotic tissues to their original position, reversal of the vector of the ageing process from an inferior and medial direction to a superior and posterior direction, and obtaining a natural appearing 'unoperated' final result. It is imperative to remember that total facial rejuvenation requires addressing three distinct regions: forehead and brows, face and neck. Each region requires a separate operation; each procedure can be carried out simultaneously with the other two or, in some instances, some can be performed independently. A brow lift will address the forehead, brows and, to a lesser extent, the upper eye lids. A facelift will address the central and lateral portions of the face, jowls and the posterior neck. A cervicoplasty (with platysmaplasty and open submental liposuction) addresses the anterior or central portion of the neck. The most consistent method to obtain a long-lasting total facial rejuvenation involves a brow lift (endoscopic), a deep plane facelift and a cervicoplasty. The purpose of this chapter is to discuss pre-operative assessment and patient selection, surgical execution and potential complications of each surgical procedure used in facial rejuvenation.

CERVICOPLASTY

Pre-operative assessment

Pre-operative assessment for the patient seeking a cervicoplasty must include evaluation of the following structures (Figure 82.1):

- Cervicomental angle
- Platysmal appearance – presence of bands or redundancy of the muscle in its central region
- Submental lipomatosis
- Position of the hyoid bone

- Position of the mandible and chin and assessment of the occlusion
- Presence of jowling and facial dermatochalasia
- Position of the submandibular glands

Ideal neck appearance should include smooth neck skin, lack of submental lipomatosis, presence of defined jawline, subtle inframandibular concavities anterior to the sternocleidomastoid (SCM) muscles, a small thyroid cartilage and a cervicomental angle of 110°. It is important to remember that an isolated cervicoplasty will not dramatically improve jowling; this deformity is mainly addressed by a deep plane facelift. Since many patients (over the age of 40) who desire a facelift also have jowlings, the author always performs a cervicoplasty at the time of a facelift. Isolated cervicoplasty is indicated in patients who have submental lipomatosis and platysmal redundancy in the absence of jowls.

SURGICAL PROCEDURE

The patient should be marked in the pre-operative room while sitting up. The inferior border of the mandible, anterior borders of the SCM muscles, inferior extent of the submental lipomatosis and any existing cervicomental crease are marked with ink (Figure 82.2). A 2–2.5 cm incision (slight curved) is marked just posterior to any existing cervicomental crease, since placing the incision within the crease can create an exaggerated and deep crease post-operatively. The procedure is carried out under general anaesthesia with intubation. After administration of local anaesthetic with a vasoconstrictor, the incision is made through the skin and subcutaneous fascia (cervical fascia). Any existing cervicomental crease (anterior to the incision) is sharply incised in the subcutaneous plane. Next, using curved facelift scissors, a skin flap with 3–4 mm of subcutaneous fat on its deep side is elevated from the centre portion of the neck all the way to the anterior borders of the SCM bilaterally. It is imperative to keep 3–4 mm of fat on this skin flap in order to prevent excessive scar contracture post-operatively. Once the skin flap is elevated and free of any ligamentous attachments to the underlying tissues, open liposuction is performed via liposuction cannulas (2–3 mm ports) in the central and lateral aspects of the neck in between the SCM muscles (Figure 82.3). Care is taken not to perform

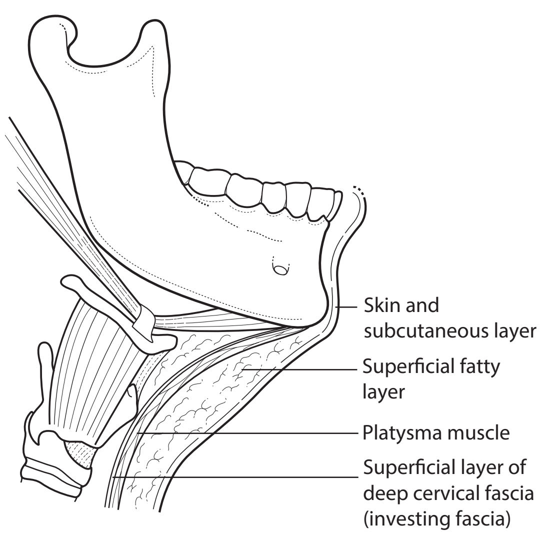


Figure 82.1 Anatomy of the central neck where a cervicoplasty is performed. (From Fattahi T, *Atlas Oral Maxillofac Surg Clin N Am*, 12, 263, 2004.)

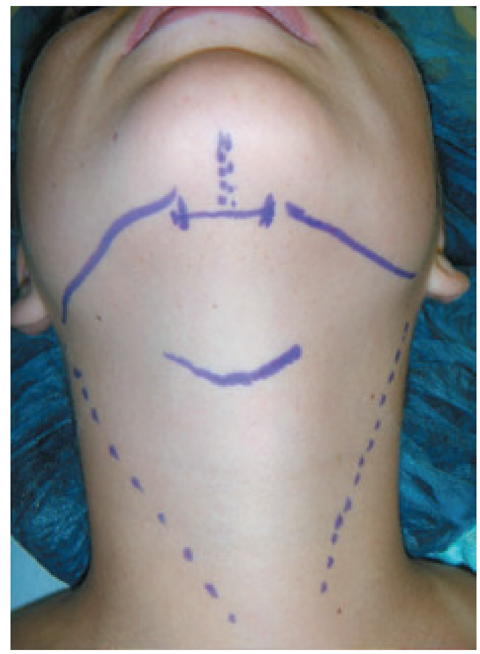
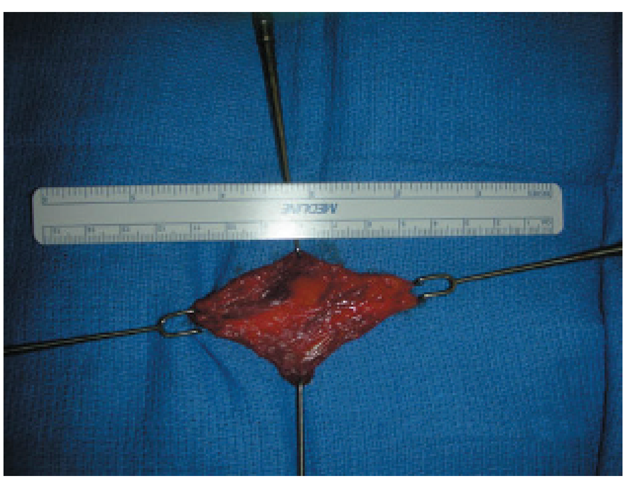


Figure 82.2 Typical markings for a cervicoplasty. The anterior borders of the sternocleidomastoid (SCM), the inferior border of the mandible and the proposed incision are marked in the pre-operative area.

Figure 82.3 Open liposuction of the submental region following elevation of a skin flap.

any liposuction above the inferior border of the mandible to prevent damage to the marginal mandibular branch of the facial nerve. Liposuction is completed when the investing layer of the deep cervical fascia is clearly visible atop the platysma muscle. Next, a subplatysmal flap is elevated and the central portion of the platysma (the redundant portion or the aponeurosis) is sharply excised starting at the genial tubercles and extending inferiorly to the thyroid cartilage. This is carried out with caution since the anterior jugular veins run just deep to the muscle in this region. The resected portion of the platysma should have a diamond or oval shape to it (Figure 82.4). The two edges of the muscle are then brought together in the midline and imbricated using 3/0 polydioxanone (PDS) sutures in a continuous locking fashion in a cephalo-caudal direction. During the imbrication of the muscle, it is important to close the patient's mouth and establish occlusion; this ensures the most posterior (deep) placement of the muscle flap. After muscle closure, the author uses a fibrin sealant (spray) under the skin flap to decrease the chances of haematoma formation; no surgical drains are ever used in cervicoplasty, facelift or endoscopic brow lift as long as fibrin sealants have been used prior to skin closure (Figure 82.5). No skin is excised around the incision since skin contracture and shrinkage over the next few weeks obviate the need for this manoeuver. The incision is closed in a two-layered fashion and dressed with Steri-strips. A pressure dressing is applied over the patient's head and is maintained for 24–48 hours.

(a)



(b)

Figure 82.4 (a and b) Appearance following excision of redundant platysma. The two edges of platysma are then imbricated together.

POST-OPERATIVE MANAGEMENT

The patient is seen in the office within 24 hours post-operatively to ensure that no haematoma formation has occurred. The pressure dressing can be removed in 24–48 hours according to surgeon preference. The patient is restricted from any strenuous physical activity for 2–3 weeks to prevent dehiscence of the platysmal closure. The patient is also asked not to turn his/her head during the same period; rather it is advised that patient turns his/her entire shoulder/body. This is also to prevent dehiscence of the platysmal closure. Perioperative antibiotics are administered for 24–48 hours according to surgeon preference.

COMPLICATIONS

Complications associated with cervicoplasty are rare. The most commonly encountered risks include haematoma formation, skin asymmetry or dimpling, damage to the marginal mandibular branch of the facial nerve and a 'cobra neck deformity'. Risk of haematoma formation is significantly reduced by the use of fibrin sealants; some surgeons advocate use of surgical drains, although it is the opinion of the author that surgical drains are unnecessary as long as a fibrin sealant is used. Skin asymmetries

Figure 82.5 Application of fibrin sealant into the surgical site in place of surgical drains.

and dimpling can occur as the skin flap contracts and re-adheres to the underlying muscle. Minor asymmetries are easily managed by massage. If persistent, scar revision and/or lysis of adhesions may be required. Marginal mandibular nerve injuries can easily be avoided by adhering to sound surgical techniques; skin flap elevation and liposuction should not be performed superior to the inferior border of the mandible. The marginal mandibular branch can cross the inferior border of the mandible in an inferior–superior direction to reach the depressors of the lower lip and can be injured if the dissection or liposuction is performed above the inferior border of the mandible. The 'cobra neck deformity' can occur when excessive and injudicious liposuction has been carried out. Also, if an adequate amount of subcutaneous fat (3–4 mm) has not been maintained on the skin flap, damage to the subdermal vascular layer can occur which can lead to excessive scarring and a 'skeletonized' look.

DEEP PLANE FACELIFT

Pre-operative assessment

It is once again important to mention that a facelift only addresses the central and lateral portions of the face, the jowls and the posterior neck. Rejuvenation of the central or anterior aspect of the neck requires a cervicoplasty which, as stated previously, is always performed simultaneously with the facelift (when a facelift is indicted) by the author. The patient desiring a facelift should be counselled on the following:

- Degree of ptosis of the midface
- Dermatochalasia of the facial skin and subcutaneous tissues
- Laxity of the facial skin
- Loss of volume (especially in thin patients along the pre-zygomatic space anterior to the masseter muscle)
- Presence of jowls
- Loss of definition of the jawline
- Presence of rhytids
- Fullness of the nasolabial fold

The youthful face exhibits no redundancy or ptosis of the facial skin and its subcutaneous tissues. Hallmarks of an attractive and youthful face also include a triangular-shaped face, high cheek bones, mild depression in the pre-zygomatic space anterior to the masseter muscles, absence of nasolabial fullness or a crease, a well-defined jawline and no jowling. A facelift, when performed properly, can reposition the ptotic facial tissues back to their original position. Since the vector of descent in the aged face is in an anterior and medial direction, redundant tissues should be redraped in a posterior and superior direction. It is important to establish pre-operatively if the patient can benefit from bony volume augmentation, such as cheek, chin or mandibular angle implants. If the patient has lost volume in the face due to the ageing process or congenital hypoplasia of the facial skeleton, simultaneous placement of the implants at the time of facelift surgery can significantly improve the final outcome.

The main benefit of a deep plane (SMAS flap) facelift is the ability to reposition the SMAS, which in turn reduces the amount of tension placed on the skin flap. It is easy to recognize patients who have had a 'skin'-only facelift by the 'pulled' appearance of the face, which can be quite unnatural. Since the ageing process is not simply limited to the skin, it is logical to address all of the tissues of the aged face during a facelift by performing a deep plane facelift.

SURGICAL PROCEDURE

The patient is marked in the pre-operative area while sitting up. The incision is composed of temporal, pre-auricular and post-auricular components (Figure 82.6). The vertical portion of the temporal incision is marked just

(a)

(b)

Figure 82.6 (a and b) Proposed incision for a facelift. Note the temporal extension just inside the hairline, the posterior extension of the temporal incision, the pre-auricular and post-auricular markings.

inside the temporal hairline. This is only about 1–1.5 cm in length. The horizontal component is also just inside the most inferior aspect of the side burn (usually at the level of the top of the helix). This portion of the incision must be bevelled about 20° for cosmesis and future hair growth. The posterior aspect of this incision is hidden behind the superior helix for about 1 cm. The pre-auricular aspect of the incision is marked from the posterior aspect of the temporal incision inferiorly following a natural skin crease anterior to the ear to just above the tragus. The incision must not be in a straight line; rather curling the incision to just above the tragus provides a much more aesthetic result. From the superior aspect of the tragus, the incision can be again made pre-auricularly or retrotragally, depending on surgeon's preference. The pre-auricular incision must also be made with a 20° bevel for a more aesthetic closure. The marking for the post-auricular component begins from the most inferior aspect of the pre-auricular incision, curls around the ear lobe, extends cephalad on the posterior ear skin, 1–2 mm from the junction of the mastoid skin and ear skin, and then gently curves posteriorly and inferiorly along the posterior hairline. The height of the post-auricular incision is at the level of the widest portion of the ear. The inferior aspect of the marking along the posterior hairline is determined by the amount of lateral pull necessary to define the jawline. The more inferior the incision, the more posterior and lateral the vector of the flap will be.

The procedure is performed under general anaesthesia with the patient intubated. After administration of local anaesthetic with a vasoconstrictor, the incision is made from the temporal aspect with a No. 15 blade, paying special attention to the areas which require a bevel. Once the entire incision is made, attention is directed towards the pre-auricular area. While applying counter traction on the cheek (assistant's hand on the cheek), a skin flap is elevated leaving adequate amount of fat on its underside (3–4 mm). This is initially done with a blade and can be advanced using facelift scissors. The anterior aspect of this flap is only about 5–6 cm (Figure 82.7).

Figure 82.7 Elevation of a skin flap.

This skin flap is easily elevated in supra-SMAS plane. The post-auricular skin flap is more difficult to elevate due to the fusion of multiple fascias in the area. Care is taken not to enter the SCM muscle while elevating this skin flap. Once an adequate skin flap is elevated circumferentially, a SMAS flap is outlined extending from the temporal side burn down on to the neck. This marking is about 1 cm anterior to the skin flap incision (Figure 82.8). Local anaesthesia with a vasoconstrictor is administered into the SMAS. Next, using a No. 15 blade, the SMAS is incised in a vertical fashion. There should be little concern with the facial nerve at this point since the underlying parotid capsule (which protects the nerve) is never incised. Once the SMAS incision has been made, blunt dissection under good visualization of the SMAS flap is undertaken in an anterior direction over the parotid gland between the zygomatic arch superiorly and 2 cm below the jawline inferiorly (Figure 82.9). The anterior

Figure 82.8 Marking of superficial musculoaponeurotic system (SMAS) incision approximately 1 cm anterior to the pre-auricular incision.

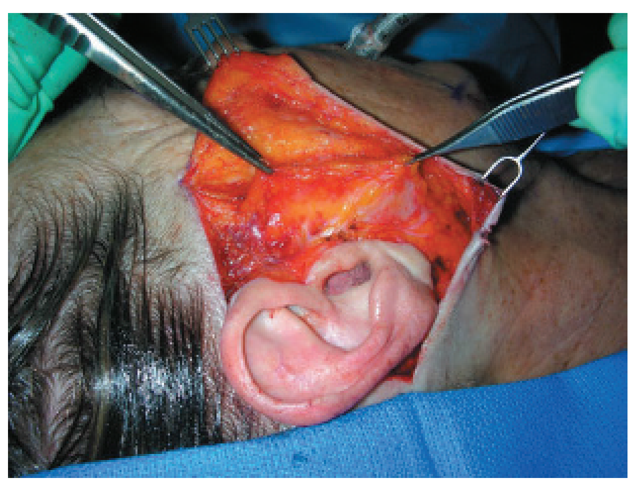


Figure 82.9 Elevation of a SMAS flap. Note retaining ligaments attached to parotid capsule deep to the SMAS.

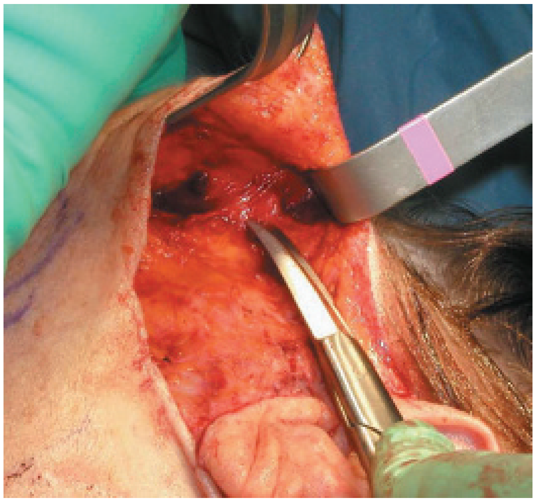
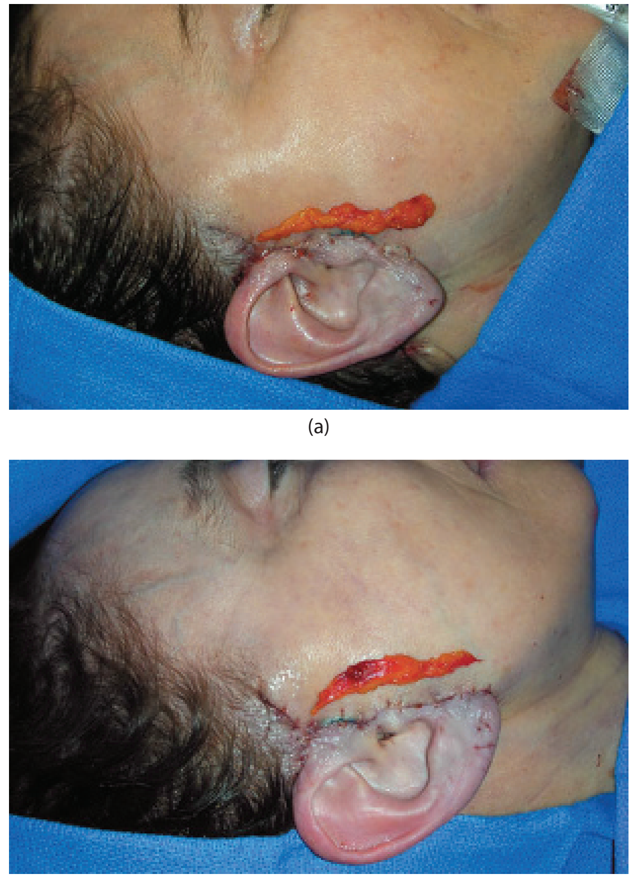


Figure 82.10 Scissors pointing to the McGregor's osteo-cutaneous ligaments.

(medial) extent of the SMAS flap is dependent on the amount of posterior and superior repositioning necessary to efface the nasolabial fold and redundant skin. However, once the zygomaticus major muscle is encountered, the sub-SMAS dissection must be converted into a supra-SMAS dissection to prevent injury to the branches of the facial nerve since almost all of the muscles of the facial expression are innervated on the deep side. The deep plane (SMAS) dissection also allows for sharp dissection of several osteo-cutaneous retaining ligaments of the face such as the McGregor's patch (Figure 82.10). Release of these ligaments allows significant elevation of the SMAS flap and allows for a much more aesthetic final result. If the submandibular glands are ptotic, they can be elevated through the SMAS flap.

Once the SMAS flap is elevated, it is placed on tension and pulled in a superior and posterior vector along its entire length. Excess SMAS is incised (Figure 82.11). Key sutures using 2/0 PDS are placed within the SMAS and anchored on the deep temporal fascia, pre-auricular perichondrium and mastoid fascia posteriorly. This should allow for a well-defined jawline. The SMAS flap is essentially acting as a carrier for the skin flap. Once the SMAS flap has been sutured properly, there should be almost no tension on the skin flap above it. The skin flap is then redraped; excess skin is incised. Care is taken to incise the skin flap in a beveled fashion as well in order to align the skin flap bevel with the pre-auricular bevel. The skin is closed in two layers using 5/0 vicryl sutures (deep) and 6/0 resorbable sutures on the skin. The author routinely used skin adhesives (DermaBond) on the pre-auricular aspect of the closure. The post-auricular aspect is closed in two layers as well, using 5/0 vicryl and 5/0 skin sutures. Prior to closure of the skin flap, fibrin sealant is sprayed on the field (between the SMAS flap and skin flap). This obviates the need for placement of surgical drains. A compression dressing is then applied to the patient head.



(a)

(b)

Figure 82.11 (a and b) Excised SMAS from left and right following skin closure.

POST-OPERATIVE MANAGEMENT

The patient is seen in 24 hours. The pressure dressing is removed to determine skin flap viability and the presence of any haematomas. The pressure dressing is reapplied for another 24–48 hours. The patient is instructed to avoid strenuous physical activities and to apply ice packs to the face to help with post-operative oedema. The patient's head must stay elevated compared to his/her body to reduce swelling. Perioperative antibiotics can be discontinued in 24–48 hours. Any permanent suture is removed in 5 days.

COMPLICATIONS

The most common and feared complication of a facelift is haematoma formation post-operatively. For this reason, surgical haemostasis intra-operatively and use of fibrin sealants is mandatory. No surgical drains are used when the author performs a deep plane facelift, although many surgeons continue to advocate their utility. If a haematoma is present post-operatively, it must be drained in order to prevent skin flap necrosis and significant post-operative scarring. When performing a deep plane facelift, damage

to the branches of the facial nerve is a possibility. It is imperative to elevate the SMAS flap in a blunt fashion and use good visualization (surgical head lights). Neuropraxia of the facial nerve branches usually resolves in a few weeks post-operatively. Other complications include asymmetries between the right and the left sides, hypertrophic scars, inadequate repositioning of the redundant skin flap, malposition of the hairline and a pixie ear deformity. Mild asymmetries between the two sides of the face may not be noticeable to the patient and usually do not require any treatment. Obviously, it is important to 'pull' equally on both sides to ensure symmetrical repositioning of the skin flap on both sides. Hypertrophic scars can be avoided if no tension is placed on the skin flap at closing. If they are present, intradermal steroid injection and constant massaging may improve their appearance. In order to avoid malposition of the hairlines, the skin flap must be adapted properly. If a dog ear is created (usually around the anterior aspect of the side burns and at the post-auricular area), it must be excised carefully. Facelift incisions that are carried superiorly on to the temple from the superior helix usually lead to malpositioning of the hairline. Pixie ear deformities occur when the ear lobe is reattached to the facial skin improperly and no longer has mobility to it. This is problematic, especially when earrings are attached to the ear lobe. Ear lobe deformities can be avoided by reattaching the most superior portion of the ear lobe to the facial skin flap. It is also important to recall the position of the earlobes pre-operatively when performing this manoeuver (patient photos in the operating room is quite helpful).

ENDOSCOPIC BROW LIFT

Pre-operative assessment

There are several key assessments necessary for any patient undergoing an endoscopic brow lift. These include the following:

- Position of the eye brows
- Presence of dermatochalasia of the upper lids
- Forehead rhytids
- Position of the frontal hairline
- Slope and length of the forehead
- Status of the corrugator muscles

An endoscopic brow lift is intended to elevate the ptotic brows and brow (galea) fat pads to a more normal position. The ideal eyebrow in a male is a straight brow that is 0–2 mm above the supraorbital rims. The ideal female brow should be arched with the medial head 0–2 mm above the supraorbital rim, apex 10–12 mm above the supraorbital rim and the tail sloping slightly inferior (Figure 82.12). The amount of brow ptosis is determined by measuring the distance in millimetres from the inferior aspect of the brow to the supraorbital rim. Dermatochalasia of the upper lids may actually resolve once the brows are placed into their normal positions. Often, patients will seek aesthetic rejuvenation of the upper lids when it is the ptotic brows which are the actual culprit. Forehead rhytids, especially deep rhytids, are improved with an endoscopic brow lift. Superficial and shallow rhytids usually require a laser resurfacing. The position of the hairline, slope and length of the forehead are also important parameters to assess. The patient with a receding hairline will certainly require modification of incisions which can make the surgical procedure difficult. Similarly, a forehead that is sloped too acutely will also present special challenges during an endoscopic brow lift. Some surgeons will not use an endoscopic brow lift if the forehead is too long; rather, a pretrichial forehead lift is used in order to shorten an excessively long forehead. If the corrugator muscles are too active and have caused formation of vertical rhytids in the nasofrontal area, then a myectomy of the corrugator is necessary to efface such rhytids.

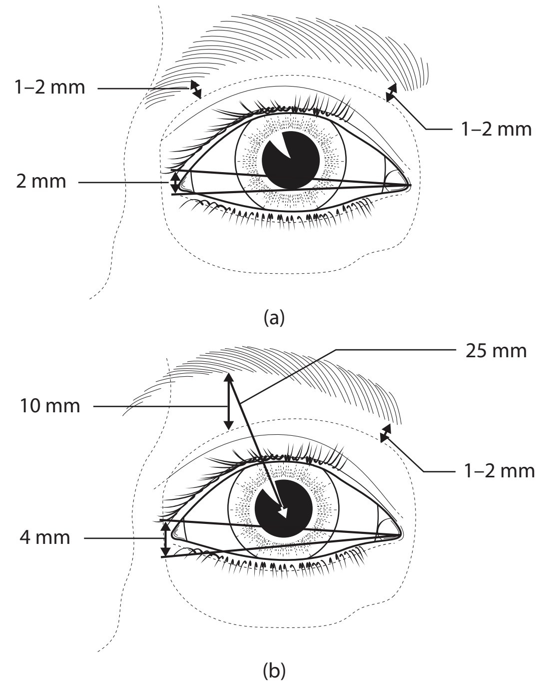


Figure 82.12 Ideal brow positions in (a) male and (b) female. (From Evans T, *Atlas Oral Maxillofac Surg Clin North Am*, 6, 118–119, 1998.)

SURGICAL PROCEDURE

The patient is marked in the pre-operative area while sitting. Most clinicians use five ports for an endoscopic brow lift including two temporal ports, two lateral (paramedian) ports and a central (median) port. The median and paramedian ports are marked 1 cm inside the hairline. Each of these incisions is 1–1.5 cm in length in a cranio-caudal direction. The central port is marked in the middle of the frontal hairline; the two paramedian ports are parallel to the lateral limbus/canthus region. The two temporal

markings are made after drawing a line that intersects the ala of the nose and the lateral canthus and extends on to the temple. The temporal port is tangent to this line, is 2 cm in length and is obliquely directed (Figure 82.13).

The procedure is performed under general anaesthesia with the patient intubated. After administration of a local anaesthetic with a vasoconstrictor, the central and paramedian incisions are made with a No. 15 blade through all five layers of the scalp onto the bone (Figure 82.14). The two temporal incisions are then made with a No. 15 blade through skin, subcutaneous layer and temporoparietal fascia. The incision stops at the superficial layer of the deep temporal fascia. All incisions should be bevelled along the length of hair follicles to reduce alopecia. A subperiosteal dissection is then performed through the median and paramedian ports. The dissection should extend posteriorly to the vertex of the skull to allow dissipation of the forehead flap in a superior and posterior direction. The anterior aspect of the dissection is visualized using a 30°, 4 mm endoscope inserted through any of the three ports. An endoscopic sheath can facilitate insertion of endoscope instruments (Figure 82.15). The dissection proceeds all the way anteriorly until the supraorbital rims and the supraorbital neurovascular bundles are visualized. A periosteal elevator is inserted through the temporal ports and is advanced medially until the temporal fusion line is reached. Also known as the condensation zone, this is the location of fusion of the deep temporal fascia, temporoparietal fascia and the pericranium. While the endoscope is in the paramedian ports, the fusion line is released under endoscopic visualization using a periosteal elevator (Figure 82.16). The fusion line must be released all the way down inferiorly until the zygomatic process of the frontal bone is reached. This causes release

(a)

(b)

Figure 82.13 (a and b) Typical markings for an endoscopic brow lift.

Figure 82.14 Appearance of a midline central/median incision. Note full-thickness nature of the incision.

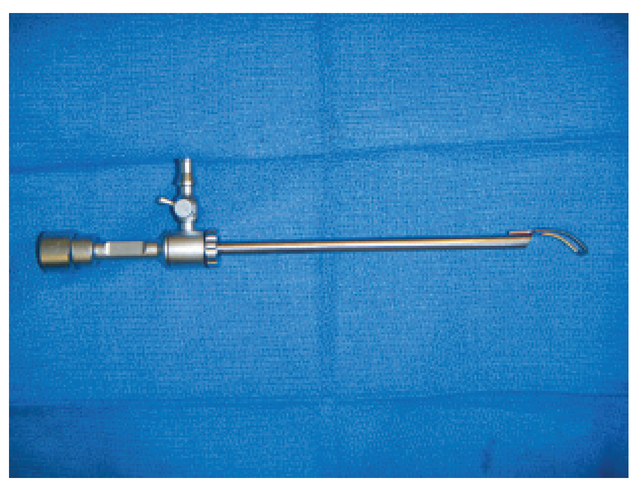


Figure 82.15 An endoscopic sheath with a curved tip. The curved tip retracts the scalp flap away from the field and allows for unimpaired visualization and dissection.

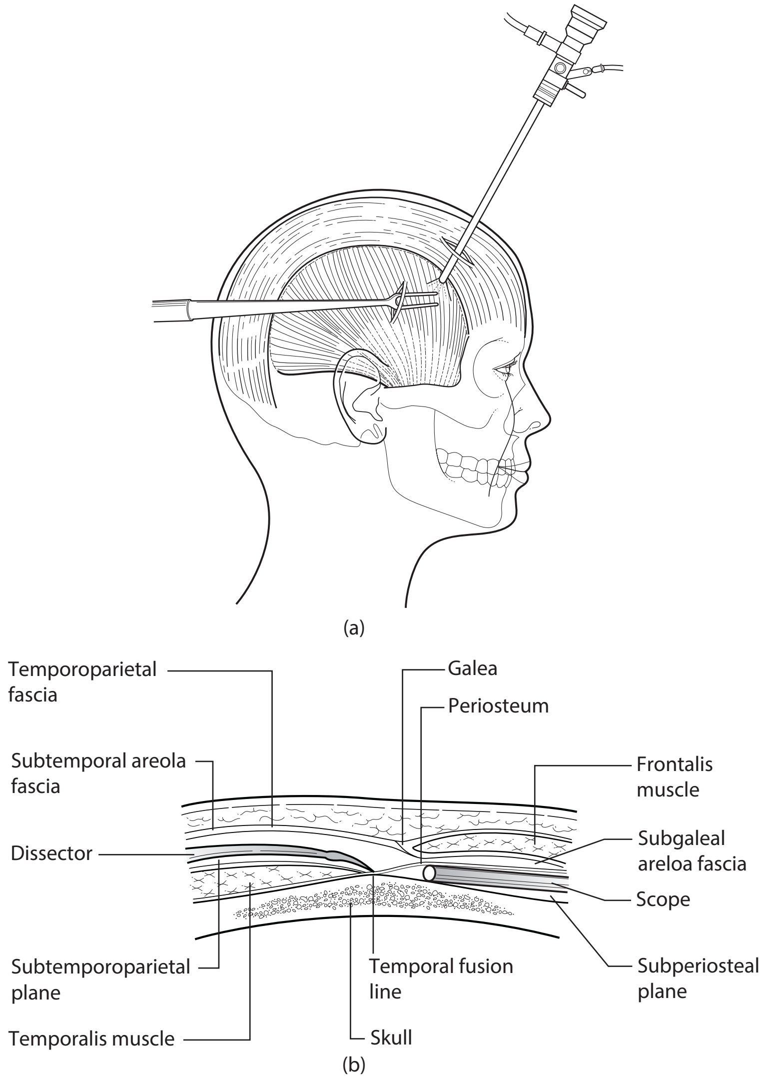


Figure 82.16 (a and b) Location of the endoscope and dissector over the temporal crest. (From Evans T, *Atlas Oral Maxillofac Surg Clin North Am,* 6, 125, 1998.)

of the orbital retaining ligaments which in turn allows elevation of the forehead and the brows. Once the entire forehead has been dissected, the periosteum must be released at the supraorbital rim/frontal bar region. This is accomplished under endoscopic visualization using an endoscopic dissector. Release of this periosteum will reveal the underlying brow fat pad (galeal fat pad, portion of the retro-orbicularis fat [ROOF]), the corrugator muscle and the deep branches of the supraorbital neurovascular bundle (Figure 82.17). This is a critical portion of the operation; failure to release the periosteum in this area will not allow sufficient elevation of the forehead. In patients who need to have elevation of the lateral canthus region and even the midface, the endoscopic elevator can be advanced down the fronto-zygomatic region onto the zygoma to elevate the entire region (Figure 82.18). If the corrugator muscles need a myectomy, using endoscopic alligator clamps, small pieces of the corrugator are grasped and removed.

After the periosteum has been released, the forehead flap must be elevated and fixated. Several methods exist to fixate the forehead flap. The author routinely uses titanium miniplates or resorbable plates to anchor the forehead flap and fixate the flap in an elevated fashion. The amount of elevation depends on the amount of brow ptosis measured pre-operatively. Using calipers, the amount of brow ptosis is added to the most inferior aspect of the two paramedian incisions. One millimetre is added to each measurement to allow for relapse. For example, if there is 5 mm of brow ptosis at the apex, the calipers are set at 6 mm, inserted into the paramedian incisions and the fixation device is placed exactly at 6 mm. Then, using a 2/0 PDS suture, the flap is elevated and secured to the fixation device. Usually two points of fixation is sufficient unless severe medial brow ptosis is present at which time three points of fixation (median, two paramedian) will be necessary. The two temporal incisions are closed while the assistant elevates the lateral brow region and the inferior limb of the incision

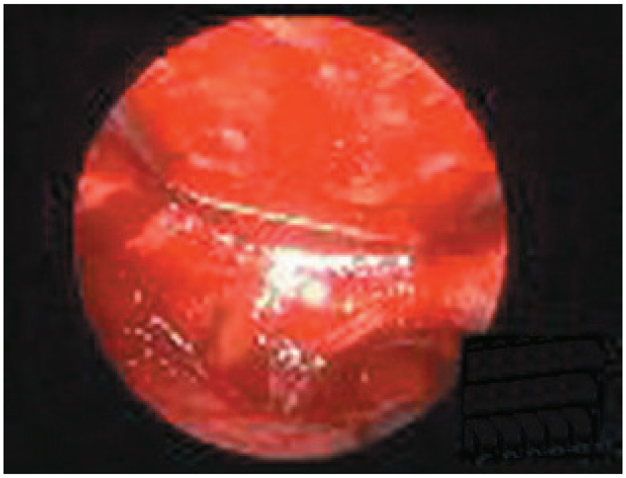


Figure 82.17 Endoscopic appearance of the supraorbital neurovascular bundle at the supra orbital rim.

Figure 82.18 Dissection over the zygomatico-frontal area to elevate the lateral canthus and midface.

is elevated and anchored to the deep temporal fascia superior to the initial incision using 2/0 PDS. This allows temporal elevation of the lateral brow. Next, to obviate the need for a surgical drain, fibrin sealant is sprayed into the surgical field. Next, the three forehead incisions are closed in two layers. Staples are used on the scalp. A pressure dressing is applied to the forehead.

Post-operative management

The patient is seen in 24 hours to remove the pressure dressing and assess any haematoma formation. If a haematoma is present, it needs to be evacuated. Most patients will experience transitory headaches following an endoscopic brow lift; the author always tells the patient of this possibility pre-operatively. The patient is instructed to refrain from strenuous exercise. The scalp stapes are removed in 10 days. Perioperative antibiotics are discontinued in 24–48 hours as per the surgeon's discretion.

COMPLICATIONS

Complications following an endoscopic brow lift are minimal. The most common complications are paraesthesia of the forehead and scalp, mild alopecia along the incisions, inadequate brow elevation, damage to the frontal branches of the facial nerve and haematoma formation. Paraesthesia of the forehead occurs due to neuropraxia of the supraorbital nerve; this usually resolves with time. Alopecia can be reduced if the incisions are made parallel to hair follicles. Inadequate brow elevation usually occurs due to improper release of the orbital ligaments and the periosteum along the supraorbital region. Damage to the frontal branches of the facial nerve should not occur as long as proper adherence to the different planes of dissection has occurred during surgery. It is imperative that the forehead elevation is under subperiosteally while the temporal dissection is atop the deep temporal fascia. This will allow protection of the nerve in the temporoparietal fascia superior to the surgical field. Mild neuropraxia usually resolves within weeks. Haematoma formation is very rare; the author routinely uses fibrin sealants in place of surgical drains to prevent haematoma formation.

Top tips

Cervicoplasty

- Do not place incision in the cervicomental crease; place it posterior to it and then obliterate the crease with scissors or knife.
- Liposuction should be performed until the investing fascia of the platysma muscle is clearly visible.
- Do not perform any liposuction superior to the jawline.

Deep plane facelift

- Proper pre-operative markings are essential.
- Elevation of the SMAS will significantly improve final results.
- Key sutures of the SMAS to the temporal fascia, perichondrium and mastoid fascia are critical.
- Use of fibrin sealants in place of surgical drains is advised.

Endoscopic brow lift

- Subperiosteal dissection over the forehead and atop the deep temporal fascia temporally is essential to minimize damage to the facial nerve.
- Releasing the periosteum and orbital retaining ligaments to ensure adequate elevation of the flap is necessary to allow proper forehead elevation.

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Aesthetic blepharoplasty

V ILANKOVAN and TIAN EE SEAH

CONTENTS

INTRODUCTION

Since the first cervical flap was reported in the early part of the nineteenth century by von Graefe, blepharoplasty has evolved into a finite concept.

The eyes are the window to the world and their limits extend to the forehead and mid-face. As the ageing process advances, the peri-orbital profile changes from convex to concave, and a full, elevated, defined, smooth contour becomes deflated, ptotic, folded and irregular as it descends. Ageing results in atrophy of fat, weakness of the ligaments and resorption and apposition of bony surfaces. It is interesting that the electromyographic characteristics of the orbicularis oculi do not alter with age.

ANATOMY

The anatomy of the eyelid is divided into anterior, middle and posterior lamellae. The skin and the orbicularis oculi form the anterior compartment; the tarsus, septum, arcus marginalis and orbital fat form the middle; and the palpebral conjunctiva and the lid retractors form the posterior compartment. In the upper eyelid, however, the posterior compartment also involves the levator aponeurosis, Muller's muscle, in addition to the palpebral conjunctiva. The lateral and medial canthal ligaments are entirely different. The retinacular attachment along the inner wall of the lateral rim is involved in the ageing process, which results in various changes including malposition of the lower lid.

Three important anatomically distinct fat deposits are directly or indirectly involved in blepharoplasties. First, orbital fat is closely related to the arcus marginalis which is more significant to lower blepharoplasty. Second, suborbicularis oculi fat has two components and is divided at the junction of the lid and cheek by the orbitomalar ligament. Third is the malar fat pad, which is inferior to the infraorbital foramen, mostly localized to the anterior wall of the maxilla extending towards the malar eminence (Figures 83.1 and 83.2).

PROBLEMS AND THEIR SOLUTIONS

Problems of the upper eyelid are excess skin with or without ptosis of the lateral brow, herniation of fat (particularly the

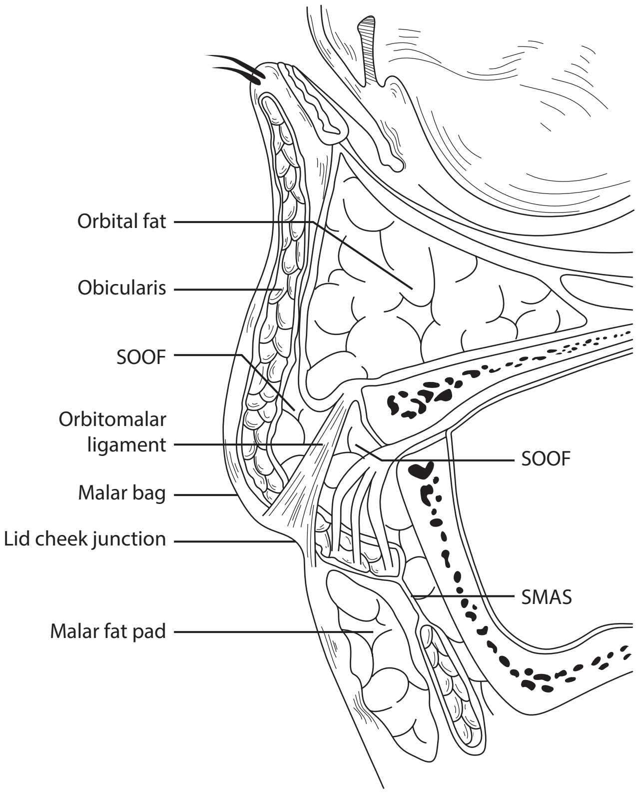

Figure 83.1 Lateral view and fat distribution. Suborbicularis oculi fat (SOOF), suborbicularis ocular fat.

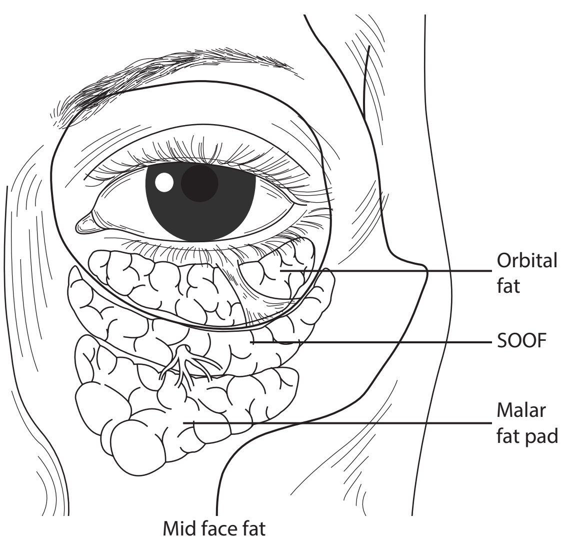

Figure 83.2 Frontal view and fat distribution. SOOF, suborbicularis ocular fat.

medial fat), and also in the middle, with prominence of the orbicularis oculi muscle and intrinsic changes in the quality of skin. Similar problems affect the lower lid and include intrinsic changes in skin, hypertrophy of the orbicularis oculi muscle and prolapse of orbital fat with deformities of the tear trough and malar palpebral groove. Lateral canthal laxity compounds these anatomical problems.

BLEPHAROPLASTY

Technical advance in blepharoplasty has evolved in the last 100 years, and the first tranconjunctival approach was described by Julian Bourguet in 1924. In the recent past, surgeons who have contributed most to aesthetic blepharoplasty are Flowers, Hamra, Barton and Hester. In 1991, we identified using cadaver dissection an avascular postseptal plane, which travels to the arcus marginalis behind the septum in front of the fascial layer that envelops the peri-orbital fat. This anatomical position, in our opinion, makes the septal reset procedure in lower lid blepharoplasty a reality.

PRE-OPERATIVE PLANNING

Patients are advised to stop smoking at least 3–4 weeks prior to surgery. Any homeopathic medication such as vitamin supplements should be discontinued during the same period. Furthermore, routine anti-coagulant therapy such as aspirin should be stopped a week prior to surgery. If there is any contraindication, this should be discussed with the patient's physician. We recommend patients to take Arnica tablets (30 g) five times a day starting a week before. Anecdotally this practice has definitely reduced bruising and swelling in the post-operative period. Patients undergoing treatment under a local anaesthetic are recommended medication as follows:

On the day of the surgery patients start oral antibiotics, usually Flucloxacillin 250 mg four times a day. Two hours prior to surgery we advocate 8-mg Dexamethasone orally, which helps to reduce the swelling and bruising. Some patients may require oral sedation, usually 10-mg Diazepam is prescribed 45 minutes prior to surgery.

UPPER BLEPHAROPLASTY

Skin marking

The aim is to create a supratarsal fold. This is usually about 10 mm from the lid margin. The skin markings are carried out while the patient is sitting up. The inferior skin markings extend medially to the upper eyelid fold. The lateral limit is just above the lateral palpebral fold. To mark the superior aspect of the skin excision, the accuracy of the excess upper lid skin should be assessed carefully. While the patient is sitting up we use an Adson toothed forceps to pinch the excess while the patients open and closes the eyes with only a mild elevation of the eyelashes.

Once the middle part of the superior marking is judged then the medial extension should follow the inferior marking to a tapered end. The lateral extension will be longer than the inferior counterpart so that the final result can also correct mild lateral brow ptosis (Figure 83.3).

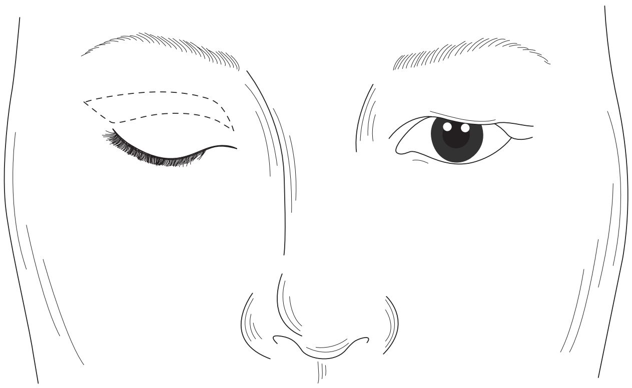

Figure 83.3 Skin marking of upper blepharoplasty.

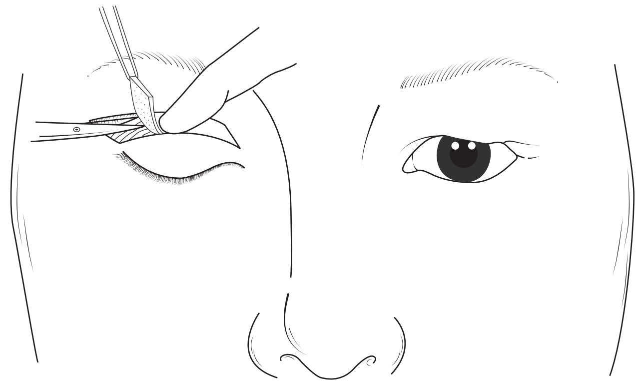

Figure 83.4 Demonstrating skin excision.

Local anaesthesia

Conservative eyelid skin removal is advisable to avoid the consequences of over correction. Surgery can be carried out under local or general anaesthetic. Even if under general anaesthesia to achieve haemostasis and a bloodless field we prefer to infiltrate 2% Lignocaine with 1:80,000 Adrenaline in a dental syringe. The injection is carried out incrementally in a subcutaneous plane to minimize bruising. Approximately 2–3 mL of local anaesthetic is adequate to carry out surgery under local anaesthetic.

Skin excision

The lower limb skin incision is carried out followed by the rest of the skin markings. We prefer to use a No. 15 blade. The skin is excised using a sharp curved scissor with simultaneous counter-traction over the orbicularis oculi muscle. Once the skin is excised, haemostasis is achieved by bipolar cauterization (Figure 83.4).

Muscle excision

Approximately 2–3 mm of orbicularis muscle is excised in order to correct the hypertrophic component. This is usually parallel to the superior margin of the tarsus and this process gives exposure to the orbital septum.

Septal incision and fat excision

Once the muscle is excised a gentle pressure along the lower lid does show the bulging fat covered by the orbital septum. The septum is incised to the entire length of the incision which will expose the preaponeurotic fat pad. Dissection to the medial fat is carried out separately which has a somewhat paler colour compared to the middle fat. The middle fat is excised in a controlled fashion whilst achieving good haemostasis. The adequacy of the fat excision would show the Whitnall's ligament.

Repair

The next step is to create an anchor point to the new supratarsal fold. There are various techniques described in the literature. We prefer to place a horizontal mattress stitch, using 5/0 Vicryl undyed suture, starting under the surface of the inferior orbicularis oculi and to the fascial attachment, just above Whitnall's ligament. Once this is achieved the skin is repaired using a 6/0 Prolene suture. The first 3–4 sutures are carried out in the middle part of the new supratarsal fold as interrupted sutures extending to complete the lateral suturing, however, the medial defect can be repaired by a continuous running suture.

Post-operative wound care

Immediately after the operation we use 1% Chloromycetin ointment as a topical application although it is not recommended for percutaneous usage. We have used this technique for the last 25 years with no adverse effect. Patients are discharged home with instructions, antibiotic and analgesics.

LOWER BLEPHAROPLASTY

Careful pre-operative assessment and planning is mandatory prior to any surgical procedure along the lower lid. The consequences of over correction in the lower eyelid surgery are much more obvious compared to the upper. The aim here is to create a normal 'S' shaped curvature to the lower lid.

Skin marking

Traditionally, a standard lower blepharoplasty is carried out via a subcilliary approach. The incision is marked approximately 2 mm below the ciliary margin of the lower lid beginning from the medial end just below the lower lacrimal canaliculi. The lateral extension is marked

extending into one of the naturally occurring creases along the crow's foot. The lateral extension varies from 5 to 7 mm (Figure 83.5).

Local anaesthesia

The anaesthetic procedure is the same as for the upper lid. If the surgery is carried out entirely under local anaesthetic approximately 3–4 mL of 2% Lignocaine with 1:80,000 Adrenaline is infiltrated subcutaneously in an incremental fashion. This volume is adequate to carry out the whole procedure.

Flap elevation and septal reset

The skin flap or skin muscle flap are the two basic operative procedures used for lower blepharoplasty.

If a skin flap is used, the skin is carefully separated from the underlying orbicularis oculi muscle. This can be done either using Tenotomy scissors or monopolar diathermy needle. Good haemostasis is achieved (Figure 83.6).

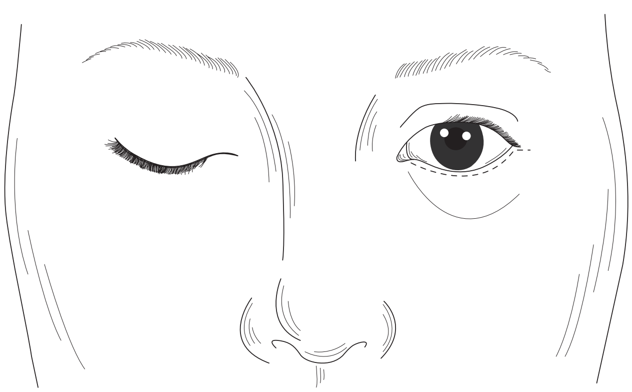

Figure 83.5 Skin marking for lower blepharoplasty with crow's foot extension.

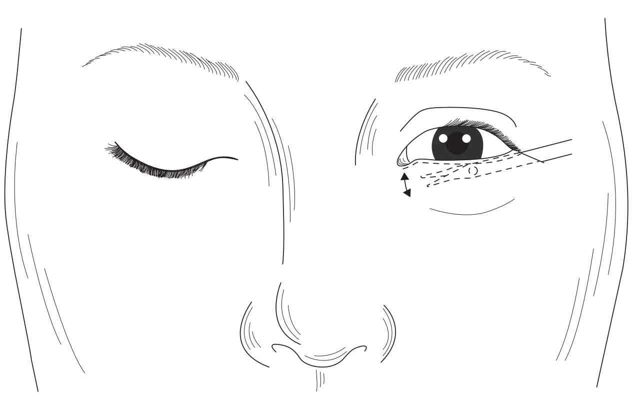

Figure 83.6 Elevation of the skin flap using tenotomy scissors.

If a skin muscle flap is used the skin incision is the same. To elevate the muscle with the flap, the incision is extended deep to the orbicularis oculi muscle. We use an 8-cm Reynolds tenotomy scissors to perform the dissection. The tip of the scissors is inserted through the orbicularis oculi muscle and the areolar plane between the septum and orbicularis oculi is defined by blunt dissection. An important measure with the skin muscle flap is to leave at least 5 mm of the pretarsal muscle intact as a site to anchor the flap once the surgery is completed. If a skin flap is raised the orbicularis muscle is split half way along the supra inferior dimension. This division would expose the herniated fat encased in a pocket completely covered by the septum (Figure 83.7).

The dissection is carried out along the plane superior to the arcus marginalis to expose the tear trough and the malar palpebral groove. This allows dissection of the herniated fat with the septum which is to be sutured along the infraorbital rim (Figure 83.8). Once the redrapping of the fat is achieved followed by haemostasis, the split muscle is repaired using either 5/0 Vicryl Rapide suture or a bipolar electric cauterization as 'welding'.

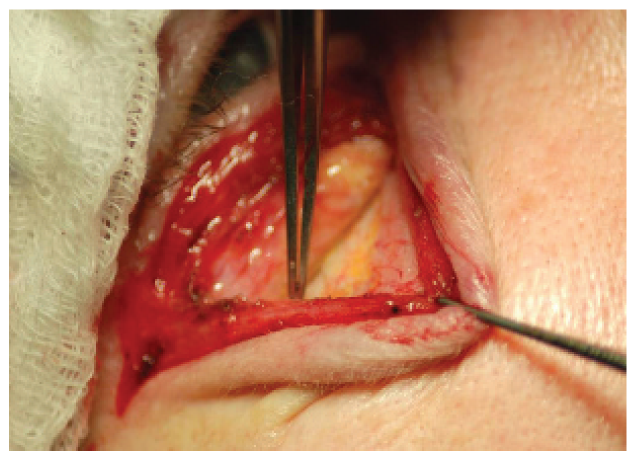

Figure 83.7 Orbital fat exposure encased by orbital septum.

Figure 83.8 Suture of the herniated fat to the arcus marginalis (septal reset). (Courtesy of Jan Stanek.)

Skin excision and repair

In both the skin flap and the skin muscle flap, once the fat management is carried out the skin is draped over the eyelashes. Passive excision of the excess skin or skin muscle is carried out (Figure 83.9). Further haemostasis is achieved. It is always helpful to divide the superior part of the orbicularis oculi muscle laterally so that plication of the muscle can be carried out using a 5/0 vicryl suture. The excess muscle is trimmed. Subsequent to that the skin is repaired with a 6/0 Prolene subcutaneous suture to the eyelid skin and interrupted sutures to the lateral extension or interrupted all the way (Figure 83.10).

The benefit of a septal reset on a background of skin flap is that the innervation to the orbicularis oculi muscle is undisturbed. The fat volume is preserved and over correction of the skin excision is minimized.

Many surgeons continue to carry out formal excision of the medial, middle and lateral fats once exposed similar to the upper blepharoplasty. The technique here is to incise the orbital septum to its entire length and careful excision of the herniated fat with simultaneous haemostasis. The rest of the surgical procedure is as described earlier.

Pinch blepharoplasty is a well-known technique where only excess skin is removed through a subcilliary approach. This corrects only the skin excess in the anterior lamellae and makes no other anatomical corrections.

CANTHAL CORRECTION

A standard procedure to correct lateral canthal weakness is a canthotomy followed by excision of the tissue and reattachment of the lower lid tarsus by a deep suture. However, this has been reported to produce webbing along the lateral canthal contour. We prefer to use a technique described by Hester (Figure 83.11a and b) where a limited composite excision of the lateral lower lid with simultaneous repair of the tarsus is done. This has the benefit of maintaining the integrity of the lateral canthal contour and correcting lid malposition.

ORIENTAL BLEPHAROPLASTY

The aim of Asian blepharoplasty is to create an upper eyelid crease which exists only in 50% of the Asian population.

Anatomy

Anatomically, the Asian eyelid is different from the Caucasian eyelid at the anterior and middle lamellae. First,

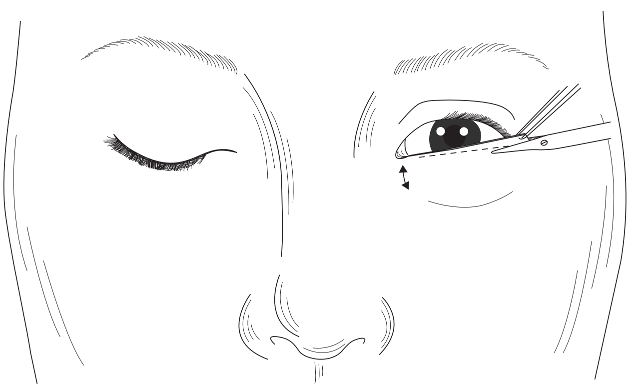

Figure 83.9 Excision of the excess skin following initial anchor suture.

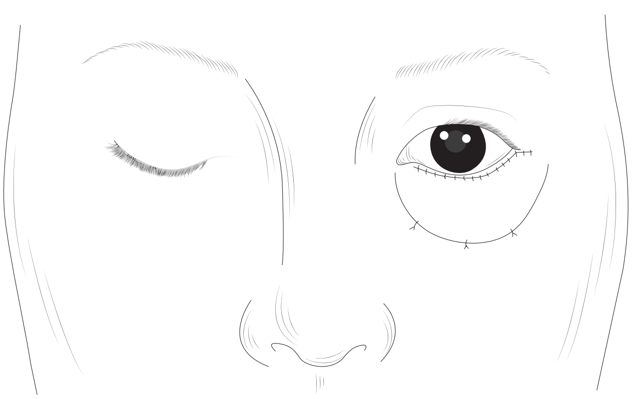

Figure 83.10 Simple interrupted suture of the skin using a 6/0 Prolene suture.

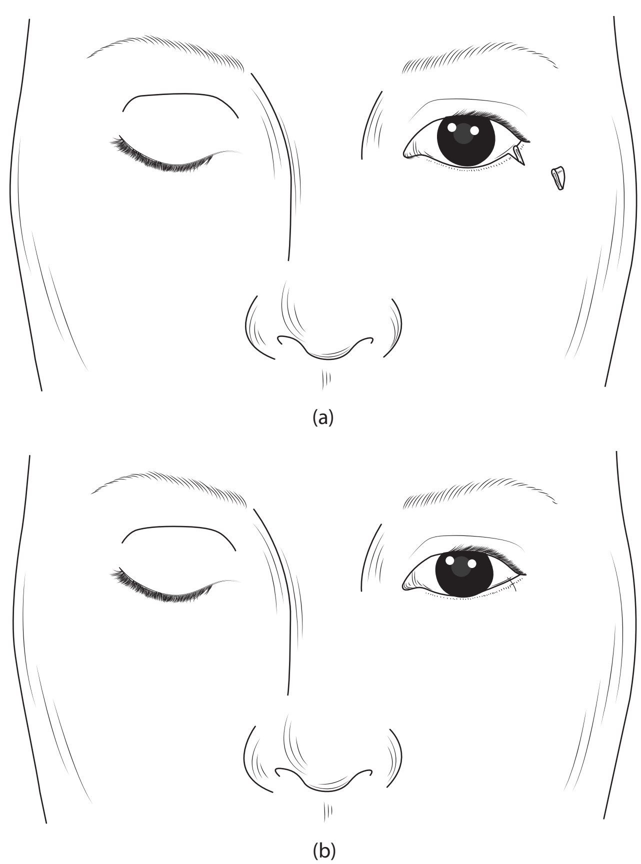

Figure 83.11 (a and b) Management for lower lid malposition by composite excision of tarsal plate and primary repair without blunting the canthal definition.

in the Asian eyelid, the orbital septum fuses diffusely with the levator aponeurosis in a more inferior position allowing the downward herniation of the orbital fat. Second, it lacks the dermal attachment of the levator palpebrae aponeurosis. Third, there is more subcutaneous and preaponeurotic fat. This creates a fuller upper eyelid look without an upper eyelid crease. There are a few ways to create the superior eyelid crease, and these can be broadly classified into suturing method and incision method.

ASIAN UPPER BLEPHAROPLASTY: SUTURING METHOD

This method is to create an upper eyelid crease by strategically placing nonresorbable sutures at the superior margin of the tarsus.

Skin marking

The upper eyelid is everted and the tarsus is measured using a pair of calipers. In the Asian population, the tarsal height is 7–10 mm (Figure 83.12). Once it has been ascertained, the height of the tarsus is marked on the eyelid skin as a smooth line that would converge medially. One to three pairs of points, each pair 4–5 mm apart, are marked on this line. The centre pair of points is in line with the pupil, while the other two pairs of points are placed equidistant from the medial and lateral canthus to the centre point.

Local anaesthesia

Topical Alcaine (proparacaine hydrochloride 0.5% ophthalmic solution) is applied on the conjunctival mucosa. This eyelid skin and the mucosa are injected with 2% Lignocaine with adrenaline at 1:80,000.

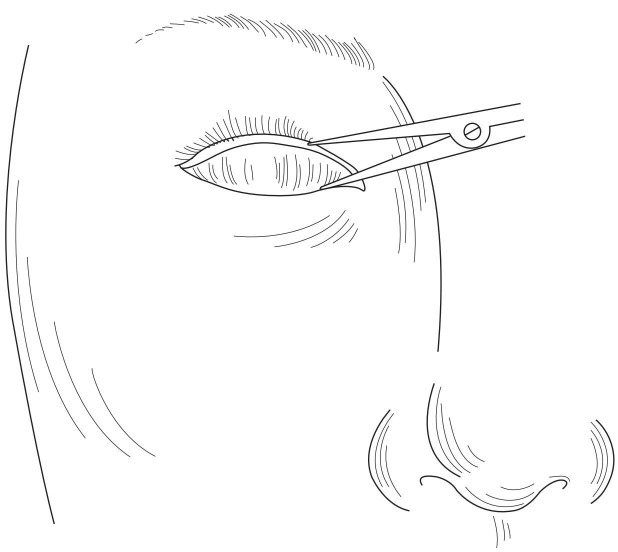

Figure 83.12 Measuring tarsal height for Asian blepharoplasty.

Suturing

Suturing is carried with CV-11 6/0 Polypropylene suture with double armed 3/8 13-mm needle commencing at the mucosa side. This is first done at the centre pair of points. The first needle is passed under the mucosa of the everted upper eyelid (Figure 83.13). Once that is done, both needles are passed from the mucosa to the skin (Figure 83.14), one at the medial and one at the distal point of the centre pair, through the skin. The medial needle is then reinserted through the medial point to pass under the skin so as to exit from the distal point. An interrupted suture is then tied and buried in the skin. This bunches up the tissues and creates a crease (Figure 83.15). At the mucosa, the suture should be superior to the tarsus so that it sits on the tarsal recesses and is kept away from the cornea.

Figure 83.13 Asian upper blepharoplasty, initial suture in suturing method.

Figure 83.14 Passing of both needles from mucosa to skin.

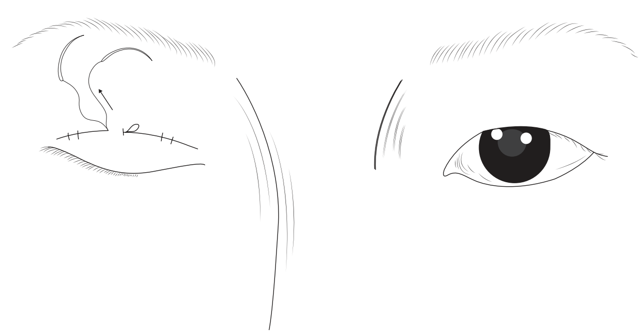

Figure 83.15 Final suture pass prior to making the knot.

Further points can be created at sites medial and distal to the central point. This helps to maintain an upper eyelid crease (Figures 83.16 and 83.17).

ASIAN UPPER BLEPHAROPLASTY: SKIN EXCISION METHOD

This method is to create an upper eyelid crease by excising skin and muscle at the superior margin of the tarsus. Occasionally, orbital fat can be trimmed if it is excessive.

Skin marking

The height of the skin excised is usually less than in Caucasian counterparts. The skin pinch technique can be used to ascertain how much skin is to be removed. Similar to the suturing technique, the height of the upper eyelid tarsus is everted and measured using a pair of calipers. Once it has been ascertained, the height of the tarsus is marked on the eyelid skin as a smooth line that would converge medially. Laterally, it curves towards the most superior crow's foot (Figure 83.18). Superiorly, the height can be determined by the skin pinch test for a mature patient with excess skin. For younger patients, the skin excision is more conservative and is about 2–3 mm in height.

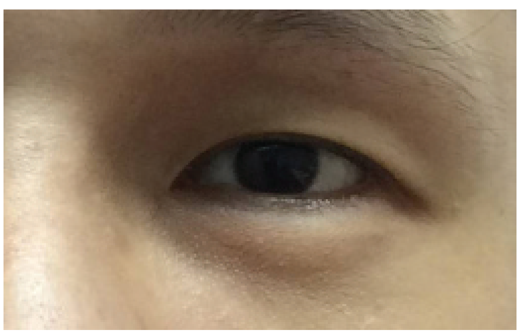

Figure 83.16 The pre-operative view of an Asian eyelid crease.

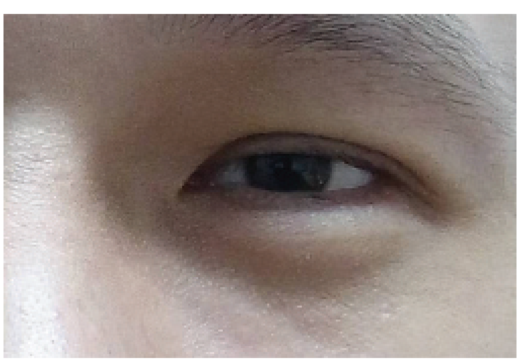

Figure 83.17 The post-operative view of the new eyelid crease.

Local anaesthesia

This eyelid skin is injected with 2% Lignocaine with adrenaline at 1:80,000.

Skin excision

The skin is excised as per skin marking (Figure 83.19). The skin is undermined inferiorly to expose the pretarsal orbicularis oculi muscle. Up to 1/3 of the pretarsal orbicularis oculi muscle can be excised (Figure 83.20).

Fat excision

The septum is divided with an electrocauthery, No. 11 blade or tenotomy scissors to expose and allow the middle

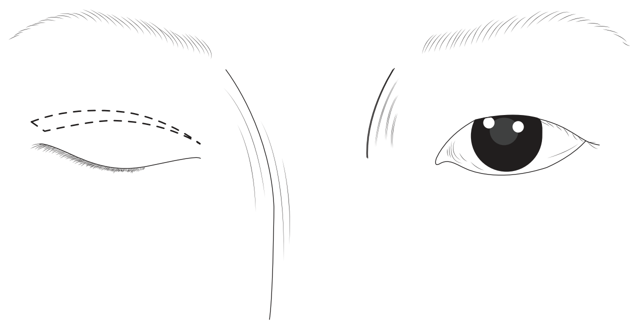

Figure 83.18 Skin marking of Asian blepharoplasty for muscle excision.

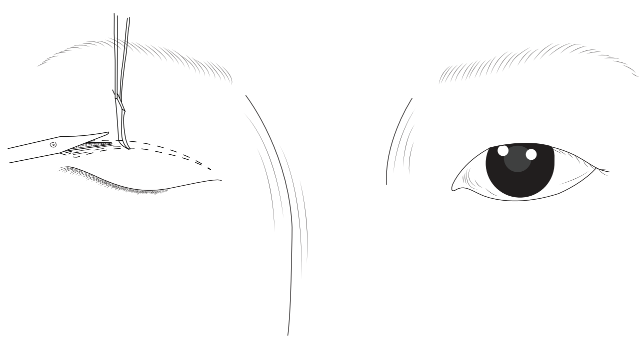

Figure 83.19 Skin excision for Asian blepharoplasty.

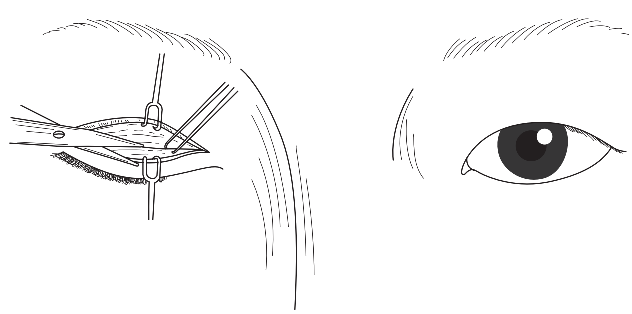

Figure 83.20 Excision of the pre tarsal orbicularis oculi muscle.

orbital fat to prolapse out. The fat to be excised is clamped with a mosquito artery forceps, and the fat excised and haemostasis achieved by cauterization (Figure 83.21).

Closure

Suture with 6/0 Prolene. Start by catching the lower eyelid skin, septum, levator aponeurosis if seen, preseptal orbicularis oculi muscle and upper skin and placing interrupted or continuous running sutures (Figures 83.22 and 83.23).

Figure 83.21 Excision of fat.

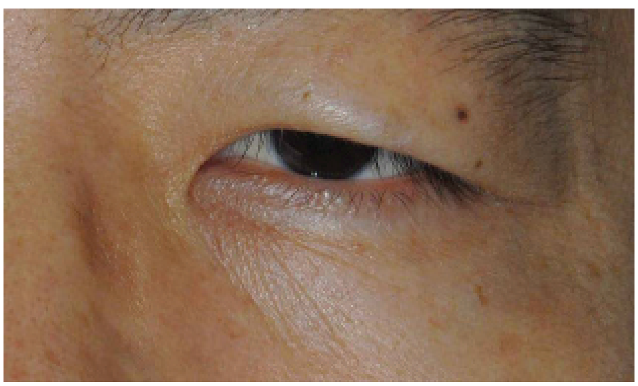

Figure 83.22 Pre-operative view of an Asian eyelid prior upper blepharoplasty.

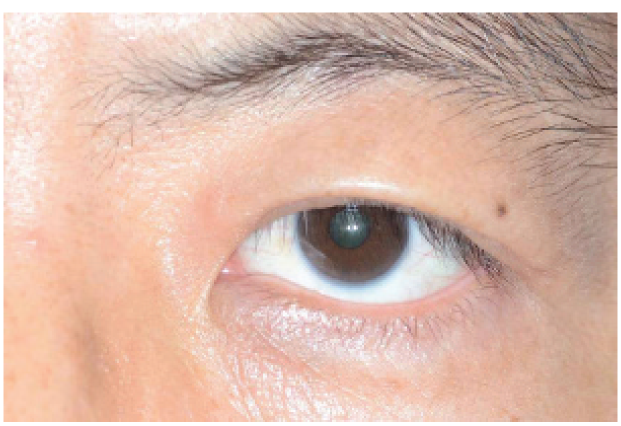

Figure 83.23 Pre- and post-operative view after upper eyelid skin and fat excision.

ACKNOWLEDGEMENT

We are grateful for the help and support of Anna Sayan and Jane Porter in preparing this manuscript.

Top tips

- Be very careful that the patient's expectations are realistic.
- Pre-operative photographs are essential as a record should the patient question the result at future date.
- Pre-operative markings should be made with the patient sitting up. The soft tissues redraw in the supine position.
- When operating remember to infiltrate the fat pads before manipulating them to prevent an acute bradycardia due to occulocardiac reflex.
- Meticulous haemostats are essential.

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84

Aesthetic otoplasty (bat ear correction)

LEO FA STASSEN

CONTENTS

INTRODUCTION

Children frequently present, or their parents or friends advise them to come, complaining of 'not liking their ears'. Their ears are too prominent, too big, too small, unusual shapes, unusual positions and, because of them, they are being teased. The problem is made worse for the child because the ears approach adult size early in the growing face. The psychological problems associated with this deformity are significant and often only come to light after discussion (Figure 84.1).

These defects are very common (3%–5%) and relatively easily corrected. The usual problem is lack of definition of the anti-helical fold and/or conchal overdevelopment. A choice of techniques is necessary. There is not one technique for all cases although it is best to rely mainly on one technique to begin with. There are so far over 100 methods described. Ely, in 1881, was the first to describe a technique for correction of prominent ears.

PRE-OPERATIVE ASSESSMENT

The most important aspect in management is assessment. Compare left with right and with normal population (n) for racial group from in front, behind and above:

- Level of ear (n = level with eyebrow): high, normal and low
- Angle between ear and mastoid process >30° is prominent
- Distance between helical rim and skull (n = 1–2 cm)
- Vertical axis: 20°–30° posteriorly (lobule to dome)
- Vertical height: approximately 5–6.5 cm (males > females and right slightly > left)
- Width = 55% of length
- Conchal size and depth
- Helix and antihelix form: poor, deficient, normal and excessive
- Scapha: size and form
- Cartilage: quality, thickness and firmness
- Presence or absence of Darwinian tubercles, sinuses and pre-auricular tags
- Photographs front, rear and individual ear ± models for difficult cases

The surgeon should know and understand the anatomy of the normal ear (Figure 84.2) and its three-dimensional position (Figure 84.3).

The ear has a very rich blood supply via the superficial temporal, posterior auricular and occipital vessels. The sensory nerve supply is via the auriculotemporal, the lesser occipital and the greater auricular nerves, and the concha also receives sensory innervation via the vagus nerve. The vascular supply and innervation are such that the procedures can easily be carried out under local anaesthetic, local anaesthetic and sedation or general anaesthesia (which should be used for children <14 years). The aim is to achieve ears of equal and normal prominence and shape with a soft gentle appearance and no evidence of breaks or pinch effects. Ideally,

Figure 84.1 Patient with prominent ears.

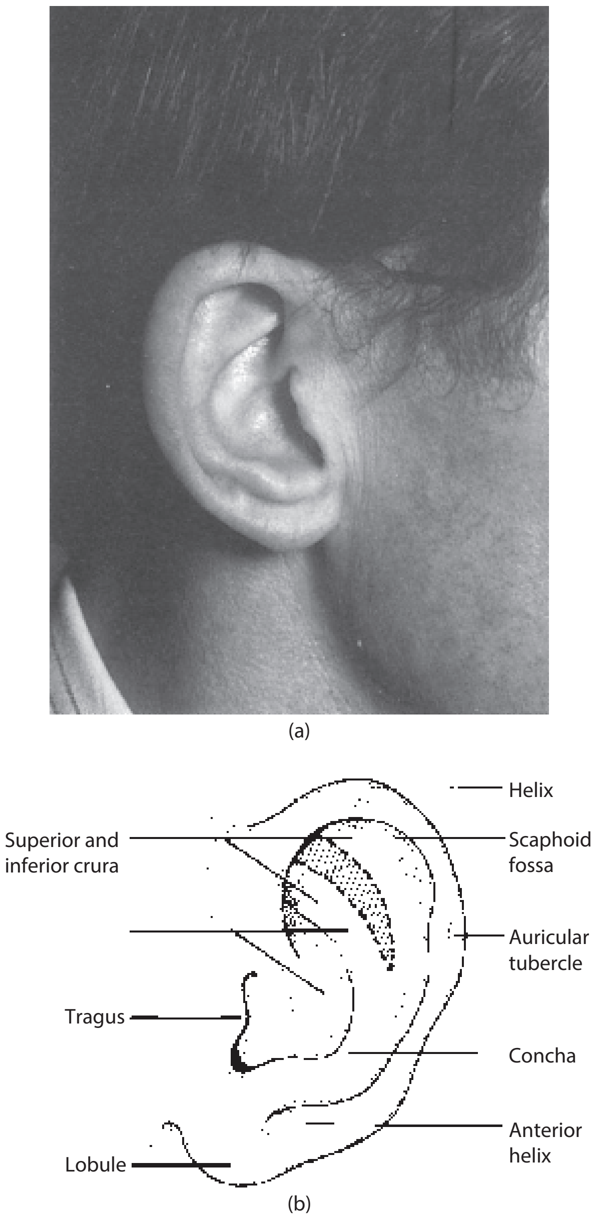


Figure 84.2 (a and b) Normal ear.

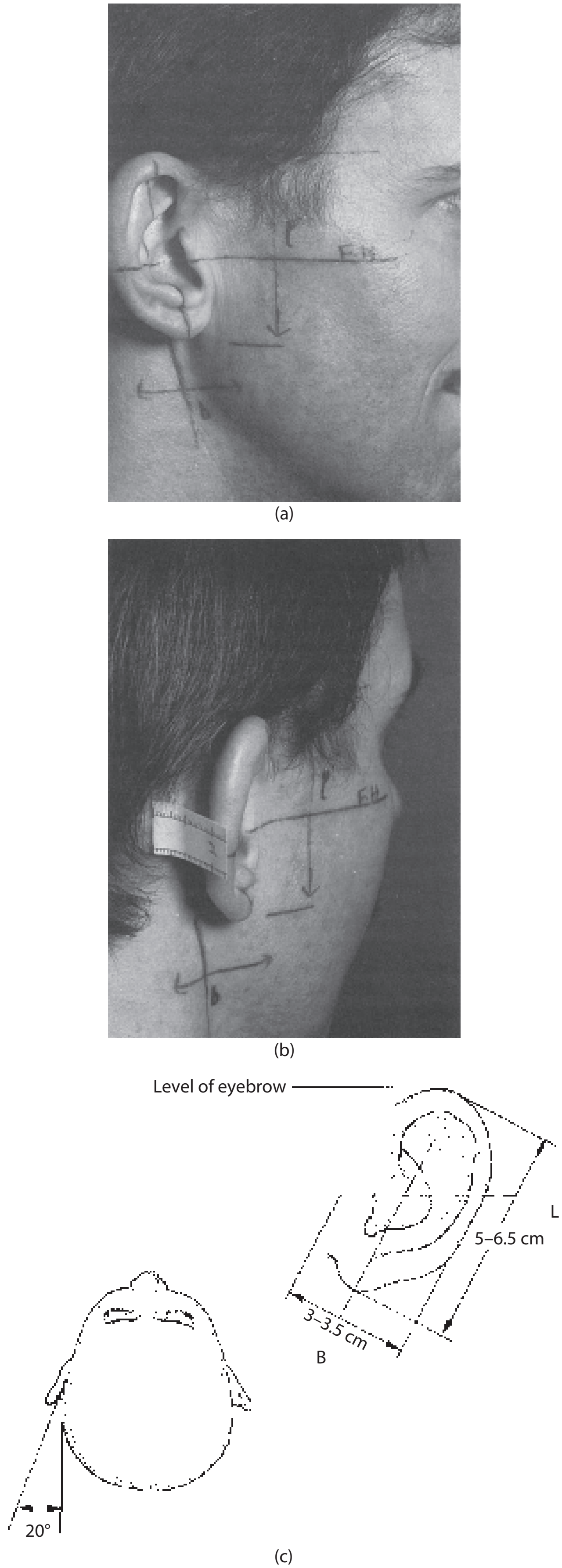
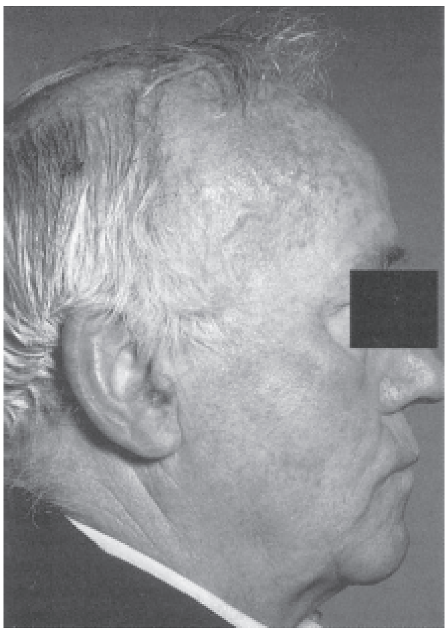


Figure 84.3 (a through c) Three-dimensional ear position.

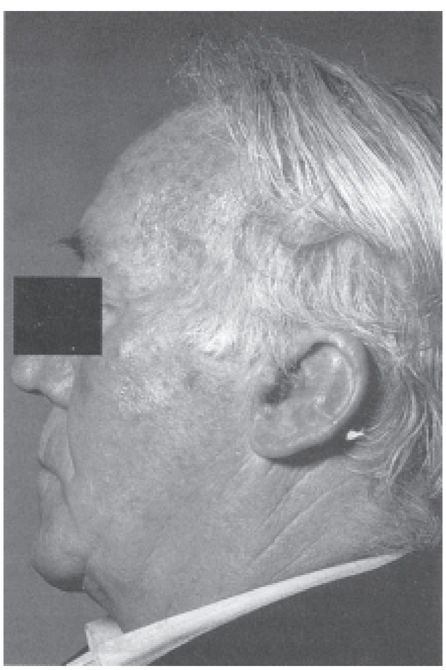
size should be equal, but not necessarily so. It is prominence that is more obvious to the on-looker rather than size (Figure 84.4).

TIMING OF CORRECTION

There is good evidence now that, if the deformity is obvious in a child at birth, it can be corrected by the application of ear moulds held in place for a month. The cartilage can be moulded significantly and permanently at this stage. Most prominent ears are not detected, however, until later.



(a)



(b)

Figure 84.4 (a) Right normal ear; (b) left ear following excision of lesion 3 × 3 cm.

The next best time to correct the deformity is when the child is older (>14 years), under local anaesthetic and sedation, unless the deformity is obvious and causing psychological problems and then the ears should be corrected at the age of 5 years before the child starts school. There is no indication to correct the deformity surgically before the age of 5 years.

TECHNIQUES

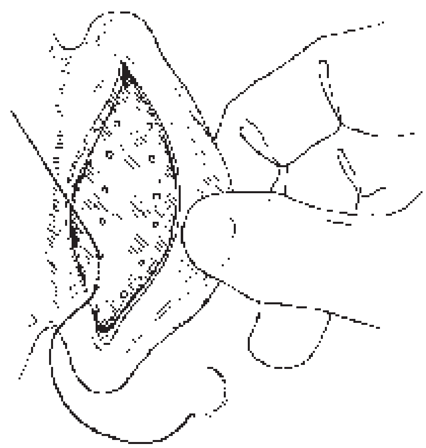
There are multiple techniques: they must eliminate tension and left and right ears should be exposed and symmetry obtained.

Mustarde technique

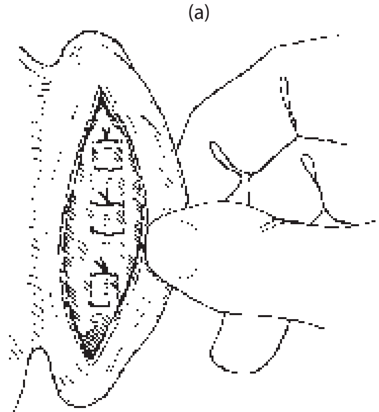
This is a very simple, efficient and reliable technique for the inexperienced surgeons, but does not address concha or scapha problems and often gives an unnatural and poorly defined appearance (Figure 84.5).

Converse technique

This is a fairly complicated but excellent aesthetic technique involving incising, mobilizing and deforming the cartilage with sutures to develop an anti-helical rim with prominent superior and inferior crura (Figure 84.6).

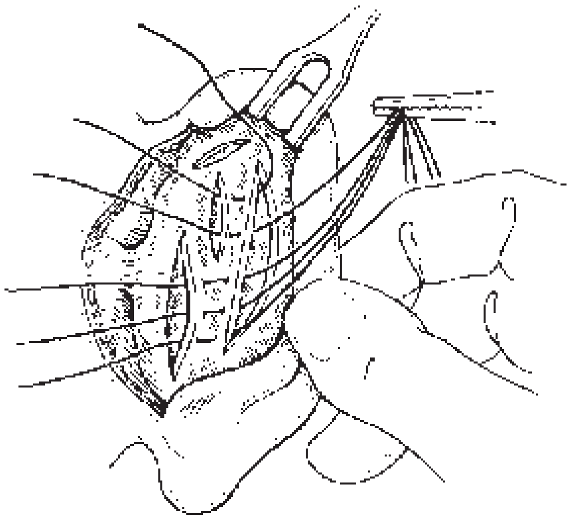


(a)

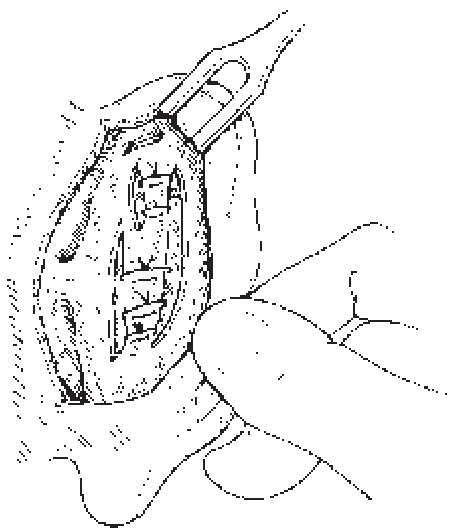


(b)

Figure 84.5 (a and b) Mustarde technique.



(a)



(b)

Figure 84.6 (a and b) Converse technique.

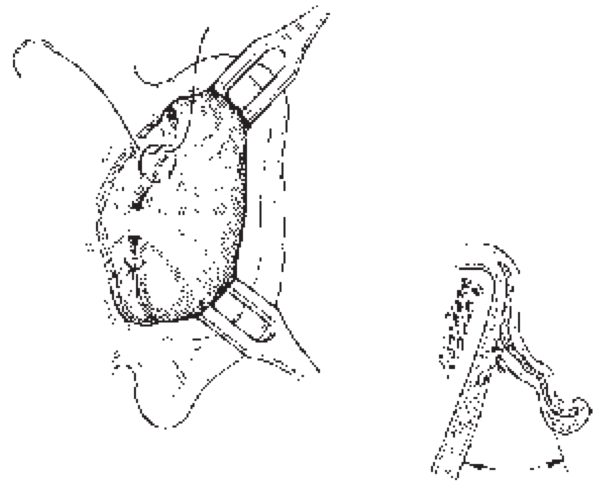


Figure 84.7 Furnas technique.

Figure 84.8 Both ears exposed.

Furnas technique

This technique involves creating space posterior to the concha to allow the concha to be pinned back without the cartilage bulging forward and occluding the external auditory meatus. It requires two stitches of non-resorbable material to be placed between the perichondrium of the concha and periosteum of the mastoid (Figure 84.7).

Stark and Saunders technique

This technique is the mainstay of the author's management supported by the Furnas conchal–mastoid suture.

Both ears are prepared with an antiseptic and exposed (Figure 84.8). The proposed antihelix and superior and inferior crura and their junction are tattooed with the use of a 22G green needle (Figure 84.9).

A dumb-bell ellipse of skin is outlined in the post-auricular area; the amount of skin to be excised is proportional to the prominence of the ears and can be judged by folding back the ear to simulate the proposed ear position. This should be excised mainly from the ear aspect (Figure 84.10).

When the ear is folded back into its proposed position, feel the maximum area of resistance and look to see if the external acoustic meatus has been compromised by the conchal cartilage bulging forward. Outline the areas of excess tension. If the conchal cartilage is bulging forward, a Furnas suturing technique is required.

Infiltrate the post-auricular area with 2% lignocaine and 1:80,000 epinephrine (adrenaline). The dumb-bell ellipse is excised and the post-auricular muscle identified and preserved (Figure 84.11).

Dissection is continued in a subperichondrial plane until the tattoo marks plus 5 mm are visible. The proposed antihelix and superior and inferior crura are

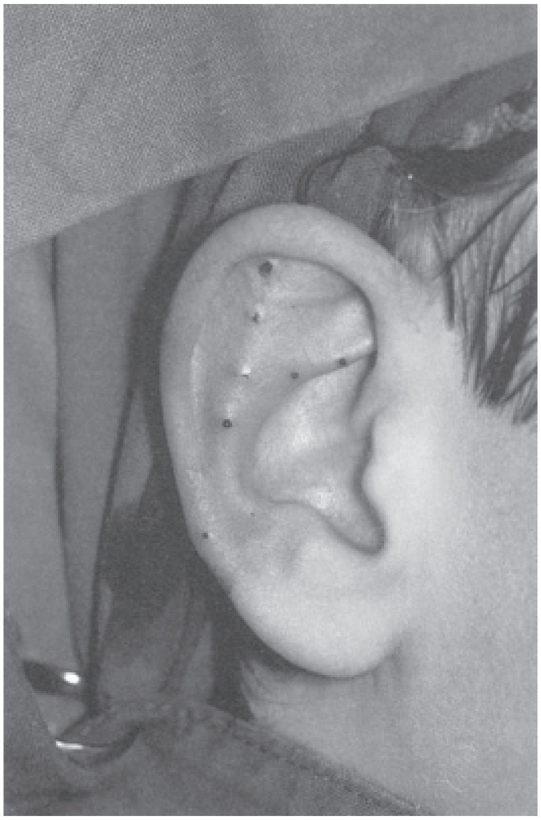


Figure 84.9 Ear markings.

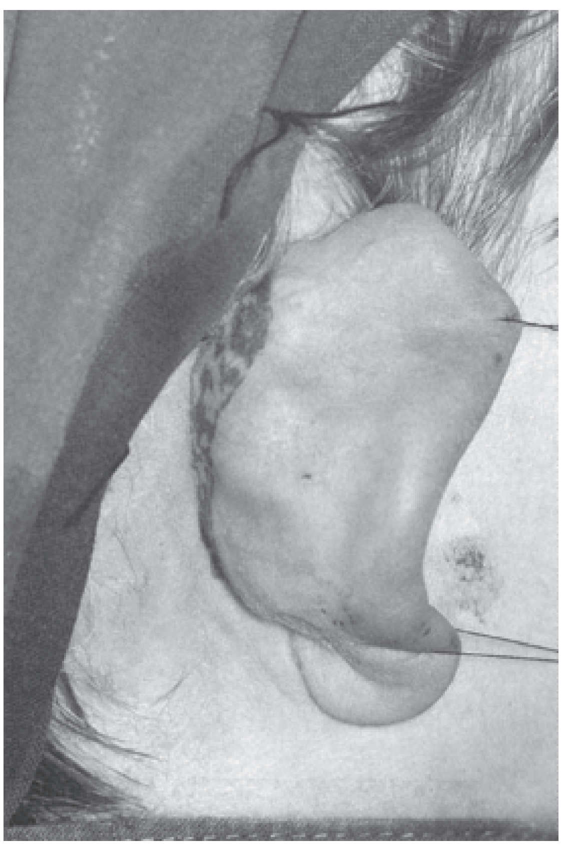


Figure 84.10 Dumb-bell skin excision.

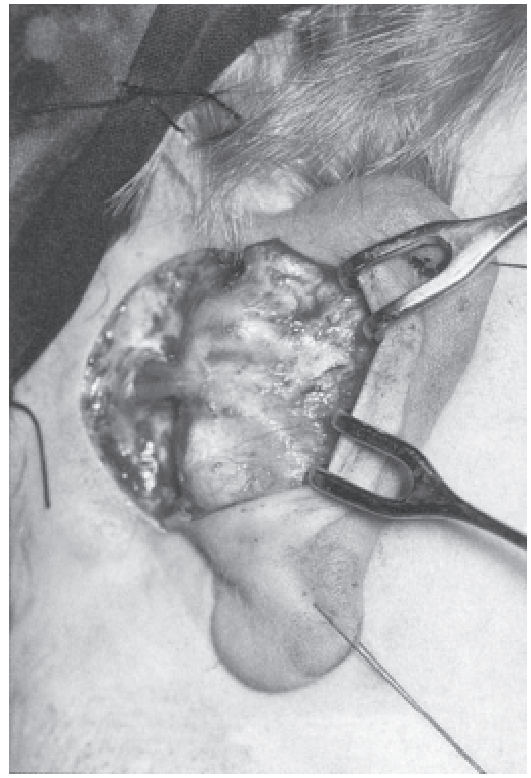


Figure 84.11 Post-auricular dissection.

drawn on the cartilage. An acrylic or diamond burr is used to weaken a 1-cm area simulating the crura and antihelix (Figure 84.12).

The cartilage is weakened until the ear can be easily bent back with no tension and no sharp ridge. Attention needs to be paid especially to the helical tail and antitragus which may require further trimming (burr or knife) to prevent the lobule protruding (Figure 84.13).

The ear is allowed to lie freely and then gently placed in its new position to allow the surgeon to decide the most advantageous position for the two to four holding sutures. The number of sutures is dependent on the extent of the original deformity. The proposed holding suture sites are outlined on the anterior ear lateral to the proposed antihelix. A 2–3-mm incision with a No. 15 scalpel blade is made down to the cartilage and then, with scissors, the cartilage is gently cleaned (Figure 84.14).

For each external incision, a 3/0 clear nylon suture is then passed from the retro-auricular dissection through the cartilage and then back again, with a millimetre bite of cartilage. This technique avoids fixation to the overlying skin.

The need for a mastoid conchal stitch is now decided. It is best to place at least one of these and, if placed, it will involve dissecting the posterior auricular muscle free from its auricular attachment to create space for the conchal repositioning. The ear is held in its proposed position and the mastoid fascia marked to allow the holding stitches to get the best purchase and best direction of support. The holding stitches are used to pick up mastoid fascia

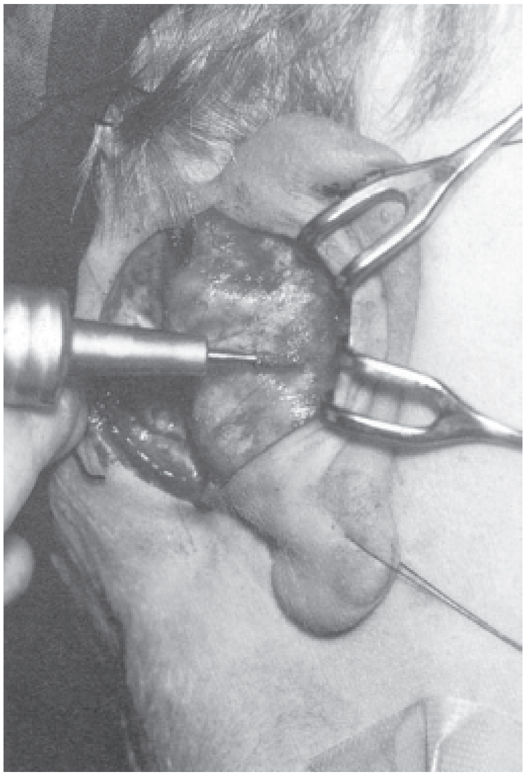


Figure 84.12 Burr to weaken cartilage.

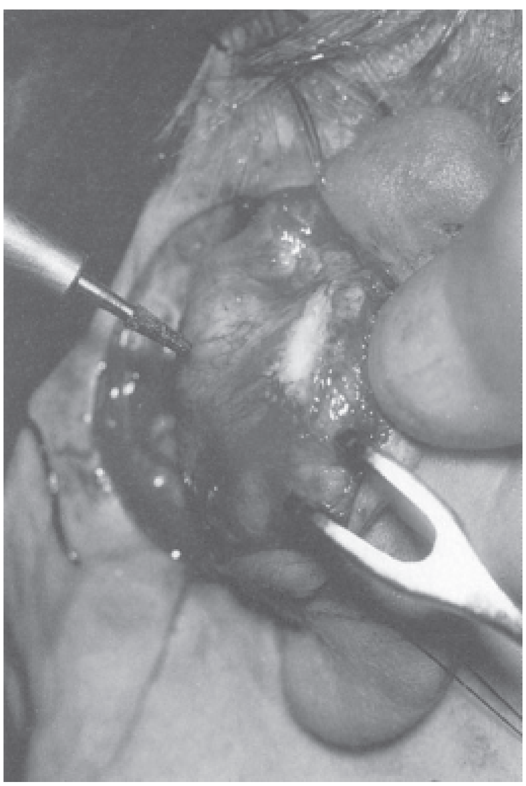


Figure 84.13 Weakening of cartilage to allow a tension-free ear position.

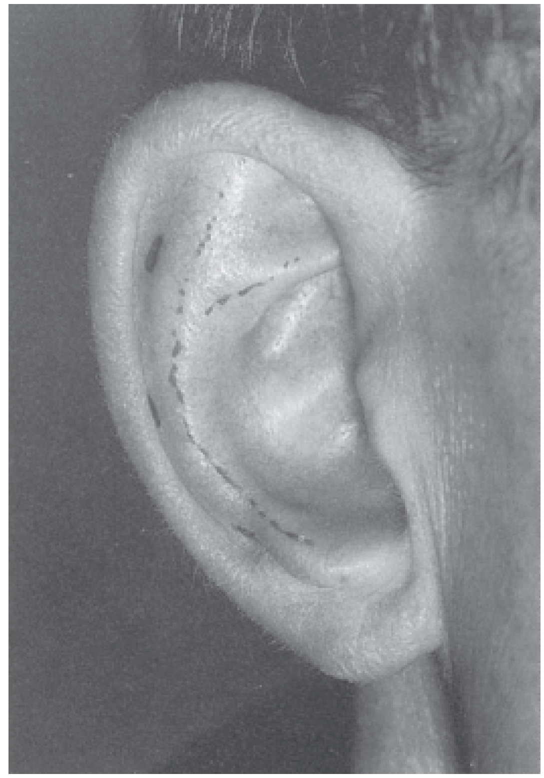


Figure 84.14 External ear incisions.

(and periosteum). The attachment to the fascia should be tested by traction on the suture before the final position is accepted (Figure 84.15).

The sutures are then clipped and the other ear is prepared. In unilateral cases, the holding sutures are tightened until the ear is slightly over-reduced. In bilateral cases both ears are reduced, one suture at a time and again slightly over reduced (Figure 84.16).

The post-auricular incision is closed with an interrupted subcuticular resorbable suture, the skin with interrupted (or continuous) 4/0 nylon. Bupivacaine 0.5% (2 mL) is infiltrated into the retro-auricular area.

POST-OPERATIVE CARE

The wound and the three stab wounds are liberally dressed with chloramphenicol eye ointment. A proflavine wool dressing is applied just to support the posterior of the ear and also to cover and shape the lateral surface of the ear. A crepe dressing in the form of a mastoid-like bandage is applied which is kept *in situ* for 7 days (Figure 84.17).

Analgesics are prescribed and the patient told to attend if moderate pain is experienced. A support dressing, such as a hairband or a knitted hat, is then worn at night for a further 2–3 weeks. The final result is shown in Figure 84.18.

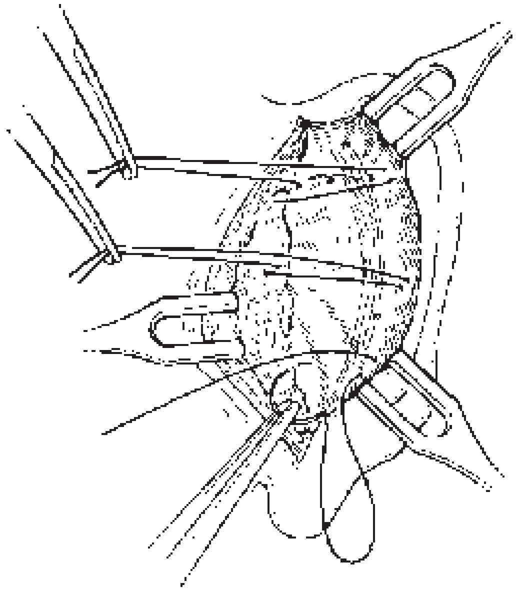


Figure 84.15 Mastoid cartilage sutures.

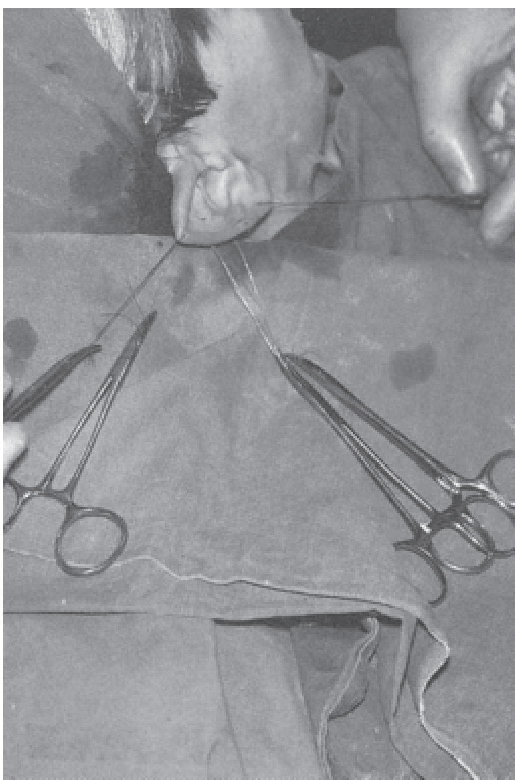


Figure 84.16 Holding sutures in place.

COMPLICATIONS

The most common complication is relapse, usually owing to an inappropriate technique or suture slippage. This warrants recorrection. Inappropriate placement of sutures can lead to the deformity known as telephone ear with the mid portion of the ear pinned back and prominence of the

Figure 84.17 Dressing in place.

Figure 84.18 Final post-operative result.

superior and inferior aspects of the ear. The most serious complications are chondritis, haematoma and infection. Haematomas require immediate drainage. Infection requires drainage and antibiotics. Haematoma and infection can lead to severe destruction and distortion of auricular cartilage, correction of which can be very difficult.

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85

Rhinoplasty and septoplasty: Closed and open rhinoplastic techniques

LUC CESTELEYN, N RAVINDRANATHAN and CORAZON COLLANTES-JOSE

CONTENTS

PRINCIPLES AND JUSTIFICATION

Rhinoplasty is the most frequently requested aesthetic procedure usually directed towards reduction, augmentation or subtle refinement of the bony-cartilaginous skeleton. The skin soft-tissue envelope (SSTE) redrapes to its new foundation. Many components of the operation can be variably affected by the healing process. The philosophy is preservation, reconstruction and cartilaginous grafting, providing tip support (TS) and creating a strong, high profile that provides and maintains the shape to the overlying SSTE by opposing the distorting scar contracture, and preserving or correcting the nasal airway.

PRE-OPERATIVE

Surgical anatomy

THE BONY PYRAMID: UPPER THIRD

The nasal vault:

1. Paired nasal bones, thick at the frontal bone junction (no osteotomies)
2. Nasal processes of the maxilla overlap the upper lateral cartilages (ULCs) (no downward rasping)

THE CARTILAGINOUS VAULT (NASAL BRIDGE): MIDDLE THIRD

The quadrangular septal cartilage acts as a supporting strut and contributes to the convex dorsum (nasal hump). It extends anteriorly as the posterior septal angle (PSA) from the anterior nasal spine (ANS) as a cantilever, to support the nasal tip at the anterior septal angle (ASA), and posteriorly articulates with the vomer and perpendicular plate of the ethmoid. Superiorly, it connects deep to the nasal bones and the paired ULC to form the cartilaginous vault. The septum's most caudal mobile aspect articulates with the medial aspect of the lower lateral cartilages (LLCs), supporting the tip, and facilitates LLC movements during respiration.

Inferiorly, the ULC are folded back on themselves at the plica nasi, where they articulate with the overlying superior border of the LLC, and their inferior borders makes an angle of 10°–15° with the septum at the valve area. The integrity of this angle is important for nasal airway patency and may be disrupted by disarticulation of the ULC from the nasal bone, rupture of the connection with the LLC and disconnection with the SSTE (Figure 85.1 and 85.2).

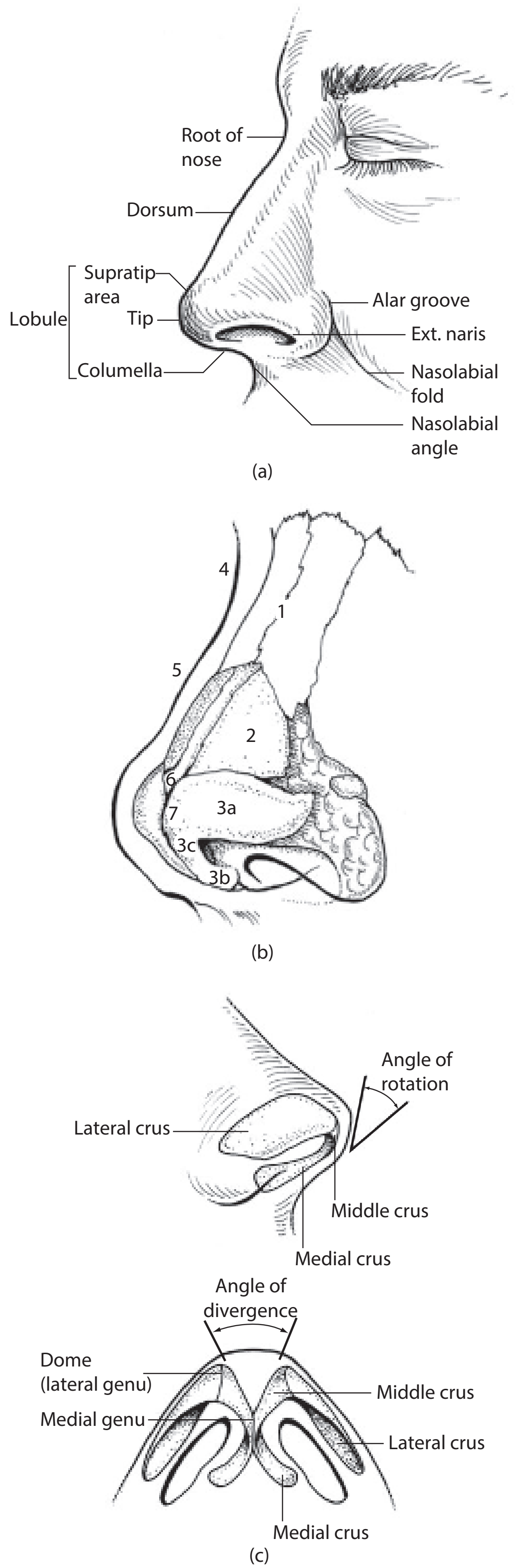


Figure 85.1 Surgical anatomy of the nose. (a) Soft tissues. (b) Osseocartilaginous structures and landmarks: (1) nasal bone, (2) ULC, (3) LLC: 3a LC, 3b MC, 3c ImC, (4) nasion, (5) rhinion, (6) ASA, (7) dome. (c) Alar cartilages and tip-structures.

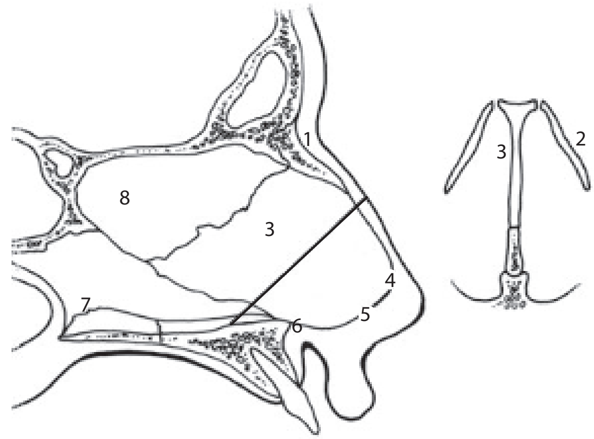


Figure 85.2 Surgical anatomy of the septum: (1) nasal bone, (2) ULC, (3) quadrangular septal cartilage, (4) ASA, (5) middle septal angle, (6) PSA-ANS, (7) maxillary crest, (8) perpendicular ethmoid plate.

THE TIP: MOBILE AND SUPPLE LOWER THIRD

The LLC is composed of a medial (MC3b) and a lateral crus (LC3a) to form an arch with domes at the level of their connection by an intermediate crus (ImC3c). The straight and thin MC is connected by the interdomal ligament and by the suspensory ligament to the ASA at the soft medial triangle of Converse. They come together in the midline to be part of the columella where they strongly articulate with the septum by ligaments in the mobile membranous septum. They end posteriorly in the MC foot plates around the ANS, and superiorly diverge (angle of divergence) as ImC, also making an angle of rotation (infra-tip break) to form the dome and then the quadrangular and convex LC. At the dome and LC the lower border of the cartilage is some distance from the nostril border; the space of superposition of skin and vestibular skin is the soft triangle of Converse or facet, to be respected by the marginal incision which follows the caudal LC margin. The LC extend down to the pyriform orifice and are connected with the ULC by fibrous and musculoaponeurotic tissue or superficial musculoaponeurotic system (SMAS). The weak triangle of Webster is located between the ULC, the LLC and the pyriform aperture (osteotomies can disrupt the triangle and result in airway obstruction).

The support of the nasal tip

Support mechanisms are divided into major and minor components (Figure 85.3). The nasal pyramid is a tripod concept consisting of the LLC (Anderson). The LC represents the upper legs and the linked MC the lower leg of the tripod. Tip-characteristics [tip projection (TP), tip rotation (TR) and nasal length] may be adjusted by alteration of the tripod limbs and the tip-supporting structures.

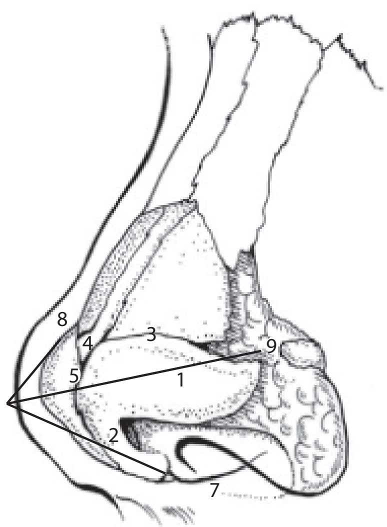


Figure 85.3 Tripod concept and elements of structural tip support (TS): (1) major, (2) and (3) minor; (1) size, shape and strength of LLC (major TS), (2) medial crural-septal ligament, (3) intercartilaginous ligament, (4) SSA and cartilaginous dorsum, (5) interdomal – suspensory ligament to ASA, (–) attachment LLC and ULC to SMAS, (7) ANS and membranous septum, (–) thickness skin and SMAS, (9) alar sidewalls.

The superficial muscoloaponeurotic system and the skin-soft tissue envelope

The superficial muscoloaponeurotic system (SMAS) covers the nasal pyramid in a continuous sheet of mimetic muscles interconnected by a tendon-like aponeurosis. The SSTE is elevated in the plane just deep to the SMAS, above the perichondrium and beneath the nasal bone periosteum to which it is adherent. The SSTE overlying the nose varies in thickness, mobility and pliability; thickest at the nasion, the supratip and at the naso labial angle (NLA), thinnest at the rhinion and the domes (Figure 85.1b). The mimic muscles of nasal animation can influence long-term healing with regards to the position of the tip, the upper lip or NLA and can be individually and synergistic overactive. A 'plunging tip' deformity can be due to overactivity of levator labii alaeque nasi (LLAN) and depressor septi nasi (DSN) muscles.

EXAMINATION

Facial analysis for the rhinoplasty patient

Besides the classical divisions in thirds and fifths, examination should include: the curved unbroken aesthetic line from the eyebrow or supraciliary ridge over the nasal root to the lateral wall of the dorsum till the tip-defining (highlight) point, the width of the dorsum, the base of the bony pyramid, the ULC and the alar base (no larger than the intercanthal distance), nasofrontal angle (NFA) and soft-tissue nasion or sellion (deepest portion of NFA): normally positioned horizontally 12 mm anterior to the corneal plate and vertically between upper eyelash and supratarsal fold.

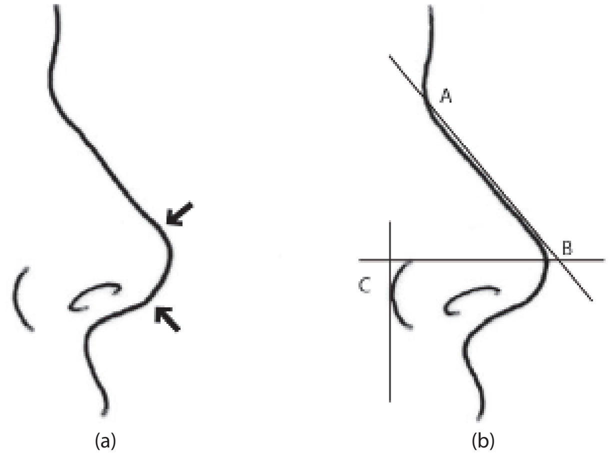


Figure 85.4 Nasal analysis: (a) morphology; (b) projection (AB: nasal length, CB: tip-base distance).

Nasal analysis

MORPHOLOGY (DEFINITION) OF THE TIP

Double break (lateral view, Figure 85.4): supra tip break (STB) and columellar-lobular angle (CLA) or infra tip break defining transition from mesial to intermediate crus. The tip position is determined by TP and TR. TP = CB (Figure 85.4), overprojection if CB >60% of AB. TR is reflected in the nasio-labial angle (90°–120°).

ALAR COLUMELLAR RELATIONSHIP

The columella should be visible and project 2–3 mm below the alar rim, as 'columellar show'. Overprojection of the columella and retracted alar rim exposes the columella and membranous septum in a 'true and pseudo hanging columella'. A hypertrophic ala is a hanging ala. Retraction of the septum in drooping tips with acute NLA diminishes the columellar show in a 'retracted' columella (Figure 85.5).

PREOPERATIVE EVALUATION

Pre-operative photographs in a frontal, lateral, oblique and base view and smiling to check the synergic muscle activity for plunging tip and gum smile, are essential. Differences in anatomical shape of the LLC, thickness, strength and recoil or 'spring' of the ASA and the LLC are assessed by palpation as well as skin thickness and quality. Oily thick skin limits post rhinoplasty tip definition because of lack of contractility even after defatting. Thin skin shows all post-operative irregularities and may necessitate interpositioning of temporoparietal fascia.

Evaluation of the airway is critical (see Chapter 87).

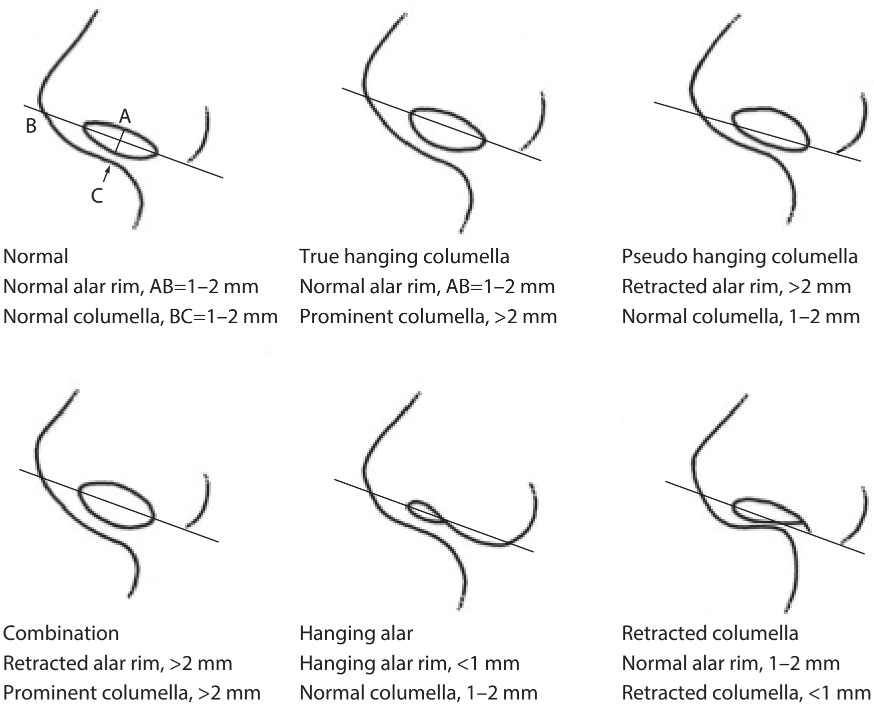


Figure 85.5 Alar–columellar relationship.

OPERATION

Approach to the nasal skeleton: Closed endomucosal versus open extramucosal

The choice is based on the anatomical deformity and the training and experience of the surgeon. The closed or endonasal access combines an interseptocolumellar (transfixion) incision with lateral intra- or intercartilaginous incisions.

In the transcartilaginous approach (cartilage splitting technique), the amount of cephalic resection of the LLC is determinated pre-operatively, before the through nasal skin and cartilage incision. The transfixion incision (TI) (Figure 85.6c) is initiated over the SSA, continues between cartilaginous and membranous septum and extends variably from SSA to the anterior nasal septum (ANS). The complete TI divides the septo-crural ligaments with potential loss of TP. The cephalic strip of cartilage is removed. The incision does not interrupt the plica nasi. A low incision, 3–6 mm from the lower border of the LC, with resection of one piece of LLC that can be reinserted if required (Millard and Peck) gives, even in thick skin noses with narrow nostrils, good access for scalpel dissection on the dorsum.

Non-delivery techniques are conservative with stable healing and minimal tip numbness only indicated for minimal tip refinements (minimal volume reduction), little TR, in thin skin noses with symmetric strong LLC needing maximal cartilage preservation.

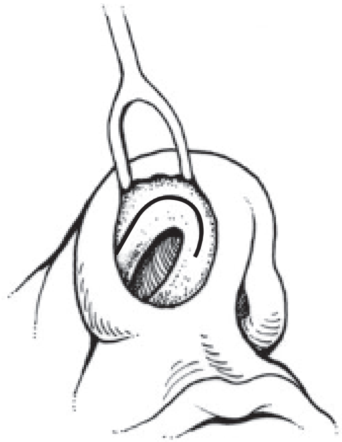
In the intercartilaginous approach (delivery technique) (Figure 85.7), bilateral intercartilaginous incisions are combined with marginal incisions following the lower border of the alar cartilages, respecting the soft triangle of Converse. The LLC is delivered as chondrocutaneous bipedicled flaps, allowing for direct inspection and appropriate tip modifications, dome sutures and asymmetry correction. The intercartilaginous incision can disturb the valve and interruption of the interdomal ligament can lead to decreased nasal TS and TP loss.

The open approach or external rhinoplasty technique (Figure 85.8) combines marginal incisions, 1 mm behind the columellar border, with a mid-transcolumellar connection. The SSTE is then dissected off the nasal skeleton under direct vision.

1. *Advantages:* Perfect visualization of the cartilages, better diagnosis, an intact valve, easier and precise grafting.
2. *Indications:* Severe post-traumatic deformities, secondary rhinoplasties, difficult and cleft noses, simultaneously maxillary orthognathic surgery to reconstruct TS and a strong profile.
3. *Disadvantages:* Increased scarring by dissection of the skin from the cartilages, potential trauma to the tip and dorsal skin by manipulation and retraction.

Surgery of the dorsum

Exposure of the osseocartilaginous vault requires sharp dissection as close as possible to the cartilages and



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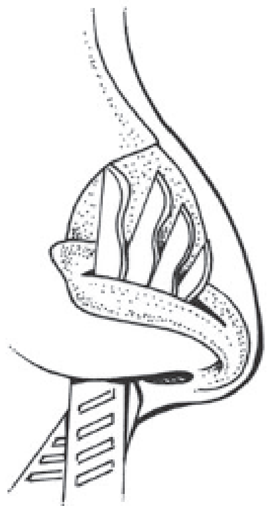

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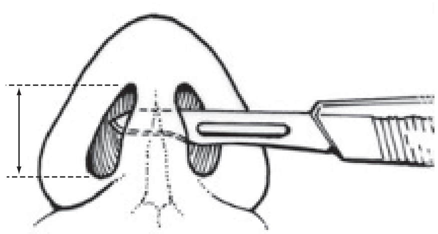
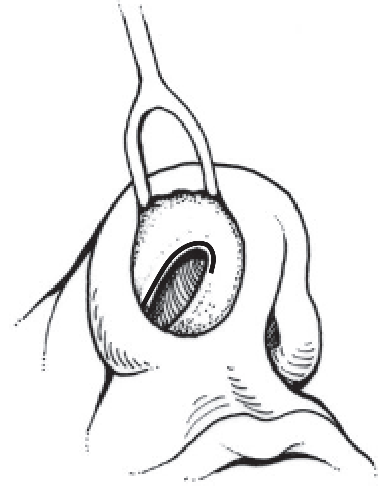


(c)

Figure 85.6 Transcartilaginous approach: (a) the cartilage splitting incision through the vestibular skin; (b) and through the LC; (c) transfixion incision (TI): the partial TI stops short of the ANS. The complete TI divides the septo-crural ligaments with potential loss of TP.



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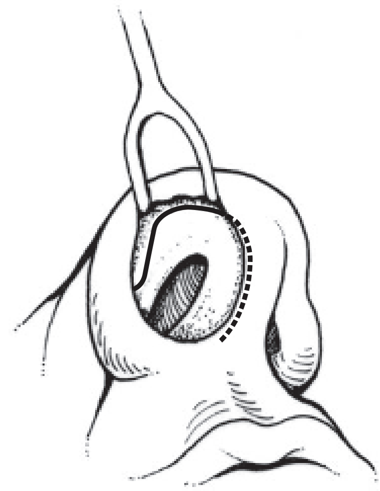


(b)

Figure 85.7 Intercartilaginous access or delivery technique: (a) intercartilaginous and (b) marginal incisions.

subperiosteally at the nasal bones keeping the SMAS intact; in thick skin noses defatting or resection of the SMAS is possible (Figure 85.9). For hump resection, an extramucosal dissection is utilized elevating the mucosa of the ULC and the nasal bones periosteum starting from the submucoperichondrial layer of the septum to prevent mucosal tearing during hump reduction and endonasal mucosal retraction. Cartilage grafting has less risk of infection, elimination or rejection in a closed compartment (Figure 85.9b). Hump resection is performed with a scalpel for the cartilage as a single unit (ULC and septum) and with a Rubin guided osteotome, introduced in the 'fish mouth' created, for the bony hump. Bony irregularities are corrected with bone scissors or upwards rasping. An 'open roof deformity' results after hump resection.

Overresection of the bony hump and underresection of the cartilaginous hump causes a 'pollybeak or surgical look'. A slight residual convexity should be preserved at the rhinion after hump resection as straight line removal of the skeletal hump can result in a concave, over-reduced bridge. This can be corrected by cartilage onlay grafting or reintroduction of a reduced resected hump (Skoog).

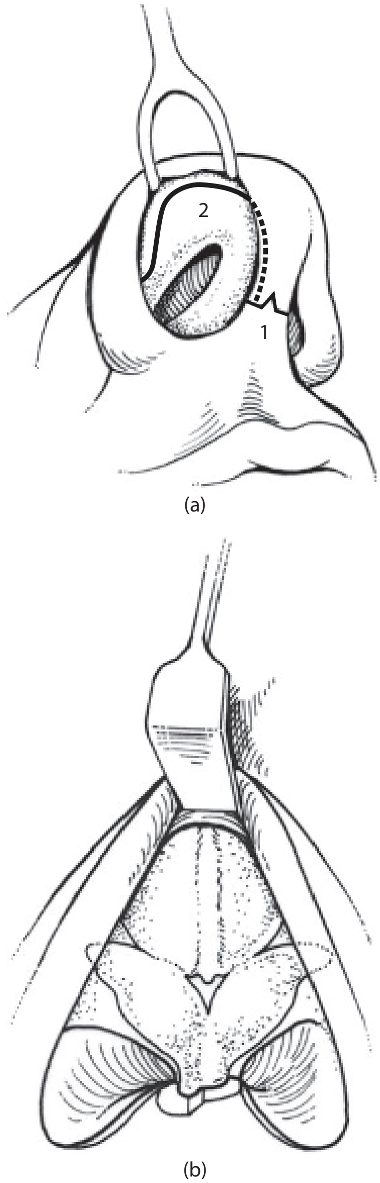


Figure 85.8 The open/external approach: (a) (1) transcolumellar, (2) bilateral vertical columellar and marginal incision; (b) elevation of the SSTE offering a direct view on the tip and middle vault.

Narrowing the nose: Osteotomy techniques

The primary indication for narrowing the nose by lateral osteotomies is to close the open roof deformity following hump resection (Figure 85.10).

The standard approach is intranasal after stab incision and tunnelling, or directly through the mucosa, at the pyriform rim just superior to the inferior turbinate, respecting the valve area at Webster's triangle. The lateral osteotomy runs low in the nasofacial groove to below the medial canthus, where it is angled towards the midline. In primary rhinoplasties, the lateral osteotomy alone is sufficient, because, by twisting the osteotome and finger pressure, a back fracture creates superior and medial fractures.

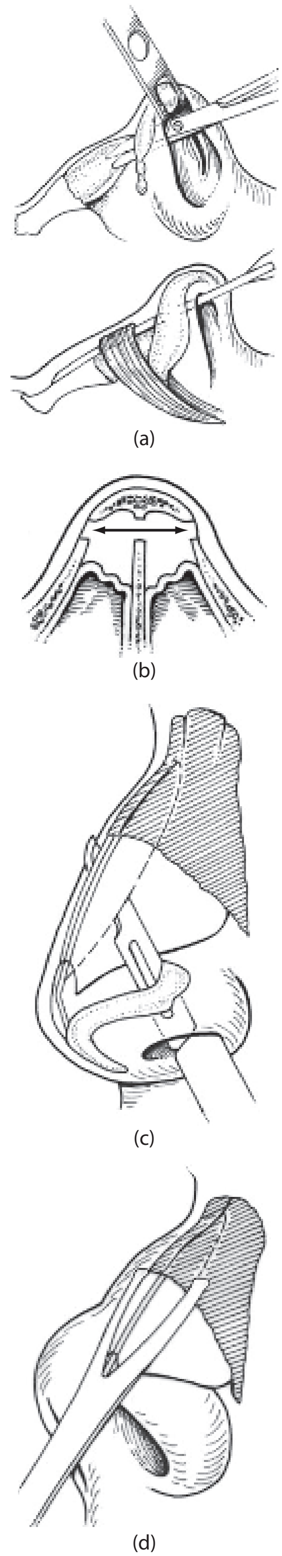


Figure 85.9 Dorsal hump surgery: (a) dissection below the SMAS and exactly on the perichondrium and ideally below the periosteum at the bridge leaving the lateral side of the nasal bones attached to the SSTE; (b) separation of the nasal mucosa away from the ULC and septum; (c) hump resection initiated with scalpel on cartilaginous portions of hump (Peck); (d) hump resection completed with rounded edges osteotome (Rubin) on the bony portions of hump.

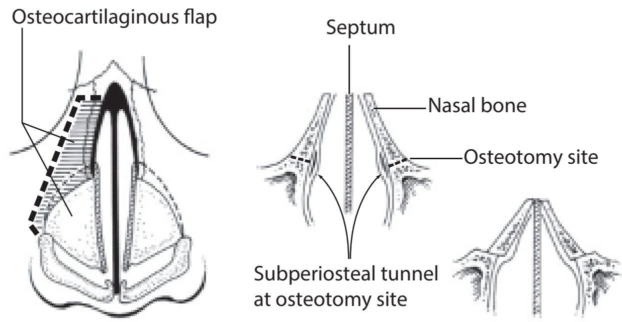


Figure 85.10 Nasal osteotomies. The 'open roof' is corrected by lateral osteotomies to mobilize the pedicled osteocartilaginous flap.

If not, transnasal medial osteotomies with an osteotome placed laterally along the septum and driven upwards till the sound change indicates thick bone, and transcutaneous superior osteotomies are performed.

For more predictable and precise osteotomies, a transcutaneous approach, lateral to the nasofacial groove, with a 2-mm osteotome, leaving no visible scar, is preferred. The superior transverse osteotomy, as well as an osteotomy of a deviated bony septum, can be carried out through the glabellar skin.

Common problems: 'rocker' formation (osteotomy too high), lateral depression (too low), stair step deformity (too medial) and recoil of bony flap or drop into the nasal fossa (too wide undermining or too thin maxilla).

NASAL TIP SURGERY

Generalities and tip dynamics

TIP PROJECTION AND TIP ROTATION

As described earlier, the nasal tip can be likened to a tripod (Figure 85.3) with the LC representing two legs and the conjoined MC a third. Selective increase or decrease in the length of the tripod legs can be used to attain the desired TP and/or TR, for example, by shortening the two superior legs of the tripod, one can increase TR and decrease TP, or by shortening the conjoined MC, one decreases TP and TR. It is nearly impossible to alter TP without changing TR (Anderson and Webster).

Cephalic volume reduction: Complete and interrupted strip, rim strip and lateral crural flap procedures

In tip refinement, the complete strip (Figure 85.11), leaving behind a 6-mm caudal LC for alar support, is a basic and conservative technique, for mild increase in tip definition with slight decrease in TP and increase in TR. The complete strip will resist upwards rotation and refinement, unless additional manoeuvres as incomplete incisions, cross-hatching or morselization are added. Sectioning the lateral parts of the LC will also increase TR. The amount of upwards rotation and decrease in TP is more important with more developed ULC.

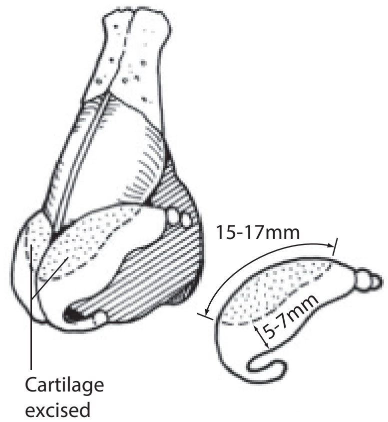


Figure 85.11 Complete strip technique.

In more aberrant anatomy, interrupted strip procedures with vertical lateral excisions are indicated; they require suture reconstruction and need supportive struts or contouring grafts to stabilize and prevent loss of projection, alar collapse, notching, pinching and asymmetry. The rim strip (Figure 85.12) and lateral crural flap (Webster) (Figure 85.12) are useful in thick skin noses, strong enough to support the alae and prevent them from collapsing, needing tip repositioning: increased TR and decreased TP.

Dome suture techniques

Complementing complete strip techniques, interdomal sutures and transdomal horizontal mattress sutures are indicated for greater tip-narrowing in broad-boxy or bifid tips with excess divergence of intermediate crura. After removing the soft tissue occupying the interdomal space, a more triangular lobule and improved support are obtained. If obliteration of the external soft triangle occurs due to medialization of the LC, the cartilage has to be trimmed (Figure 85.13).

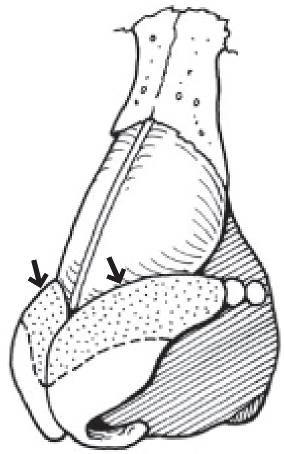
SEPTAL SHORTENING

Essential in correction of a long nose, performed through a (high) TI or directly in the open technique. The shortening encroaches on the ANS and can be modified as illustrated in Figure 85.14.

Adjunctive procedures

SEPTOPLASTY, SEPTAL GRAFT HARVESTING

Septal surgery is performed to correct septal deviations with airway obstruction or aesthetic problems due to anterior deflections, and to harvest (osseo) cartilaginous grafts. All displaced structures should be exposed with



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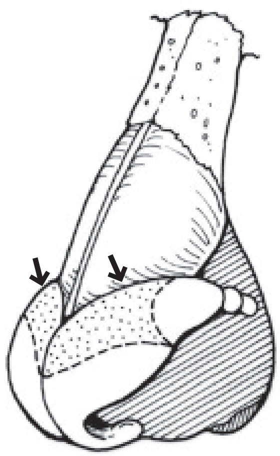
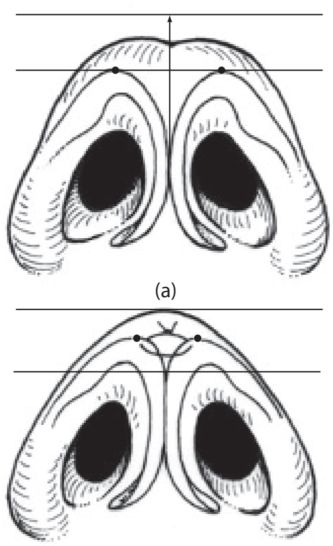


(b)

Figure 85.12 Cephalic volume reduction: (a) rim strip technique; (b) lateral crural flap (Webster) technique.



(a)

(b)

Figure 85.13 Interdomal sutures technique.

Figure 85.14 Septal shortening (Aiach).

limited mucoperichondrial detachment and maintaining 1 cm of dorsal and caudal structure to prevent dorsal saddling, tip drooping, columellar retraction and septal flaccidity.

Septocolumellar (hemi) TI

Through a hemi-TI down to the spine to the cartilage, a submucoperichondrial dissection is performed with a Cottle's elevator. If fracture adhesions, cartilage overlaps, or severe scarring interfere, the area is infiltrated with local anaesthesia to facilitate further elevation.

Anterior septal corrections

Anterior cartilaginous thickenings can be thinned by shaving, concave cartilaginous deviations are corrected by resection of excess inferior cartilaginous combined with full thickness incisions on the concave side of the contralateral pedicled cartilage to break the spring (memory) (Figure 85.15). The swinging-door technique is used to reposition a displaced caudal septum. After unilateral elevation of the mucoperichondrial flap, the septal cartilage is excised along the floor of the nose and repositioned on the premaxillary crest, and fixated on the contralateral mucoperichondrium by a bur hole in the ANS. Bony spurs and angulated deformities (see Chapter 87) need resection or osteotomy.

Posterior septal corrections and for graft harvesting

Cartilage incision 1 cm posterior to the border of the caudal septum. Elevation of the untouched mucoperichondrium on the contralateral side where needed, mostly at the junction of the cartilage–maxillary crest.

Septal modifications, after positioning of a long small speculum, by:

1. Resection/osteotomies: most common method for septal correction and graft harvesting. Deviations limited to the posterior septum are treated by endonasal submucous resection after bilateral mucoperichondrial flap elevation. A 1-cm caudal and dorsal L-shaped strut is left attached to the perpendicular ethmoidal plate and maxillary crest–ANS area to maintain support. Cartilage and bone for grafting can be harvested.
2. Segmental scoring/weakening.

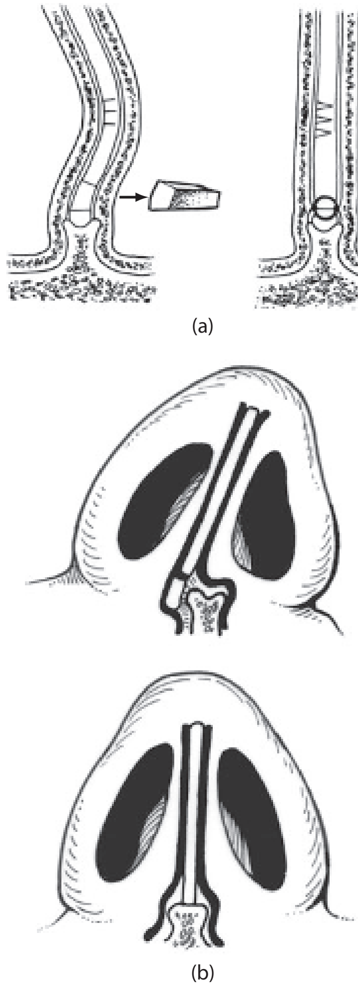


Figure 85.15 Anterior septal corrections through a hemitransfixion incision and unilateral flap elevation: (a) incision on the concave side and partial resection; (b) repositioning of caudal deflections with displacement from bony groove, resection of cartilaginous spur, osteotomy of palatal/vomeral crest offending medial reposition of caudal septum.

3. Swinging-door flaps, indicated in angular deviations of the dorsal strut, which are incised at the angle to 2 mm of the dorsal border. Repositioning in the midline and splinting for stabilization before multiple cartilage incisions interrupt a twisting dorsal strut, as well as stabilization of the caudal septum on the ANS.
4. Morselization, only possible after bilateral flap elevation, is sparingly used, as results are unpredictable.

Tardy's modified incision after Killian

In Tardy's modified method (Figure 85.16), a vertical sinuous incision sited just cephalically to the caudal end of the septum and proximal to the mucocutaneous junction, avoiding scar formation or retraction in the cutaneous portion of the caudal septum allows full septal exposure through retrograde dissection to and around the caudal septum while maintaining the vital medial crural footplate attachment to the septum.

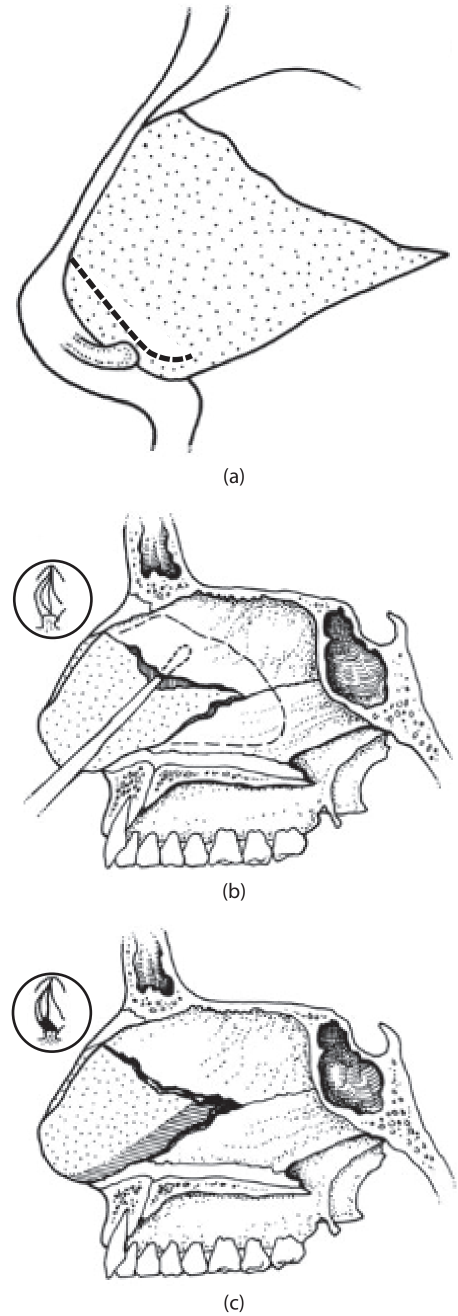


Figure 85.16 Tardy's septoplasty technique: (a) serpentine mucoperichondrial incision 2–3 mm above caudal septum border; (b) unilateral mucoperichondrial flap, disarticulation of the cartilaginous septum and contralateral subperiosteal dissection; (c) resection of subluxated cartilage (and bone) along the floor of the nose and replacement of the anteriorly pedicled septum as a 'swinging door' to the midline.

After unilateral flap elevation, and if osseocartilaginous grafts are not needed, disarticulation with slight pressure with the elevator at the chondro-osseous junction or in previous fracture lines, exposing the contralateral perichondrium permitting contralateral submucoperiosteal dissection. This often allows the deviated cartilage to return to the midline as a 'swinging door', sometimes after resection

of fibrous tissue bands, subluxated cartilage or bone along the nasal floor. Correction of bony obstructions is performed with a biting forceps. Cartilaginous obstructions are corrected by incisions in different directions through the cartilage but not into the opposite mucoperichondrium, to create multiple cartilage islands, supported and nourished by the opposite intact mucoperichondrial flap.

Transoral sublabial approach

Use

- Children with caudal subluxation. An intact caudal septum is important for the development of the columellar–labial complex.
- In secondary septoplasties and post-traumatic rhinoplasties for anterior bony crest (re)sections or graft offers the possibility of separate elevation of the flaps to reduce the chances of perforation.

Open or external approach

The open rhinoplasty technique offers a remarkable exposure for anterior and infero-anterior septal corrections, secondary septoplasties and graft harvesting from the ASA and caudal septal border to correct caudal deviations.

Separation of the domes and the MC to the ANS, with submucoperichondrial dissection cranially to the ethmoid. Caudally, separate elevation of the periosteum by tunnelling from the ANS on the floor of the nose. By semicircular sweeping motions both tunnels are connected over the chondro-osseous junction area to prevent lacerations. Bilateral dissection is possible but in angulated deformities, a unilateral attachment is preferred for stabilization. The medial crural support is re-established by suturing the MC together post-septoplasty.

From the anterior septal border to correct anterior deviations in secondary septoplasties, where the dissection from the caudal border is impossible due to scar formation, and has to be dissected from anteriorly at the middle third after section of the ULC at their septal junction; modification and graft harvesting can then be carried out behind the area of adherences.

At the end of the procedure redundant bony-cartilaginous fragments can be repositioned as free grafts between the septal flaps, to prevent a flaccid septum (floating during inspiration and expiration). Through-and-through mattress resorbable sutures reapproximate the septal flaps and stabilize the repositioned fragments. Inadvertent perforations of the mucoperichondrium are meticulously closed if they are opposing each other. Incisions are closed and disrupted supporting ligaments: interdomal and medial crural–septal attachments are restored. Bilateral soft silastic stenting is placed for 5–7 days (Figure 85.17).

Nasal grafting

Grafting provides shape and definition, establishes solid TS, opposes scar contracture and distortion of the SSTE and functionally grafting is used to improve and maintain an open nasal airway.

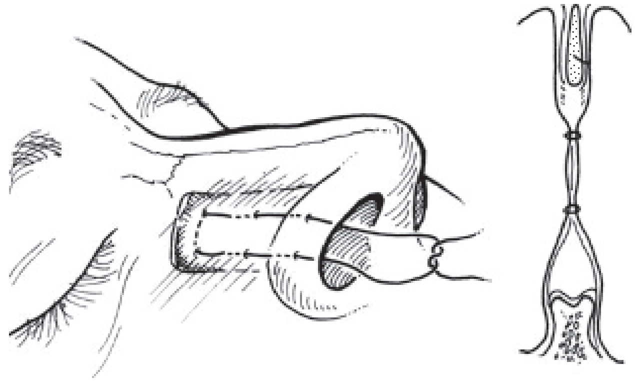


Figure 85.17 Reapproximating the mucoperichondrial septal flaps and stabilizing the septal remnants.

Septal cartilage is the preferred source of grafting material. Other excellent sources include remnants of the resected osseocartilaginous dorsal hump and the cartilage obtained from the cephalic trim of strong LLCs. Conchal ear cartilage can also be used. Thin bony plates from the perpendicular ethmoid and vomerine septum may be used where a more rigid graft is needed. Description of all grafting techniques is beyond the scope of this section, they include columellar struts, tip onlays, infratip lobular grafts etc. In addition to these tip grafts, contouring grafts are frequently required.

Alar base surgery

Aesthetic narrowing of the nasal skeleton and tip must be balanced by concomitant reduction of the alar base. Alar surgery is one of the final steps in aesthetic rhinoplasty in a conservative and symmetric manner (Figure 85.18).

SURGICAL TECHNIQUES

- Internal nostril floor reduction preserving the nostril sill provides subtle improvement in repositioned nasal tips without visible scar.
- Alar lobule excision at the nostril floor and sill results in reduction of flare as well as in slight reduction of the alar bulk, and provides medial alar repositioning.
- In reduction of overprojecting tips, alar wedge excisions reduce the overall length of the alar sidewalls.
- Maximal alar reduction with medial repositioning will be effected from the alar sliding flap technique, with a generous incision in the alar–facial junction. Reduction of the volume, curve and flare will result, the extent of each dependent on the angulation of the excision. Skin repair is accomplished with intradermal absorbable suture. Skin sutures are placed 1 mm above the alar–facial groove to avoid sebaceous glands located in the junction. The repair can be further supported and enhanced with the use of an alar cinch suture of 3/0 PDS.

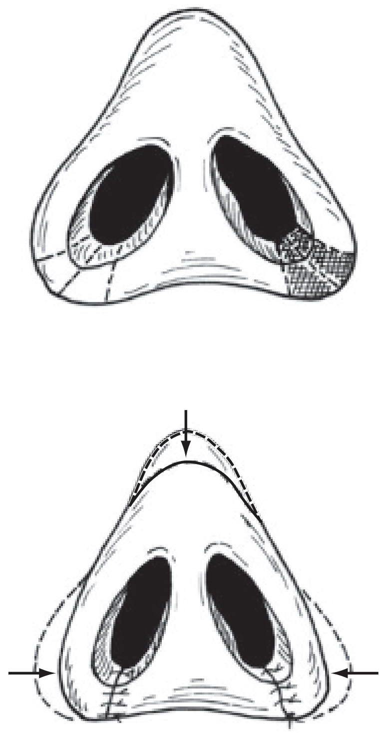


Figure 85.18 Alar base surgery: Alar resection in combined vertical and horizontal part.

HOW I DO IT: A MODIFIED OPEN STRUCTURE RHINOPLASTY TECHNIQUE

General anaesthesia with orotracheal intubation is preferred. The nose is packed with neurosurgical cottonoids in a cocaine–epinephrine (adrenaline) solution for vasoconstriction and shrinkage of the mucosae; local anaesthesia (0.5% xylocaine – 1:100,000 epinephrine) is infiltrated between the skin and the skeleton and submucosally.

The mid-columellar incision (inverted V) to the level of the medial crura at a site just anterior to and above the flare of the medial footplates is made with a No. 15 blade. The transcolumellar incision is connected to bilateral columellar marginal incisions running 1 mm behind and parallel to the rim of the columella. The lateral part of the marginal incision is placed along the caudal margin of the lateral crura. The back of the scalpel is used to palpate the edge of the cartilage to identify the correct position for the lateral incision. A double skin hook retracts the alar margin while simultaneously applying finger pressure over the LLC to evert the caudal margin. Then the hook is placed between the lateral portion of the marginal incision and the columellar portion, with simultaneous traction on the nasal skin with a single hook to make the connecting incision, respecting the facet or soft triangle of Converse, which should be preserved; incisions too close to the nostril rim can result in alar notching or distortion of the facet.

Using small pointed serrated scissors or a scalpel, the SSTE overlying the medial crura is dissected without injuring the underlying cartilage. By using three-point counter-traction, sharp dissection along the medial crura and LLC is performed in the avascular immediate supra-perichondrial plane, preserving the subdermal plexus and avoiding flap breakdown. Flap elevation is carried laterally to the point of attachment of the lateral crura with soft tissue. The interdomal ligament is not disturbed.

The loose connective tissue (Pitanguy's ligament) overlying the ASA at the soft supratip triangle is resected and an avascular supraperichondrial plane is identified over the lower dorsum. At the rhinion, the remainder of the dissection of the nasal bones is performed subperiosteally, using sharp dissection. An Aufricht retractor is placed and lateral bands between the SSTE and the osseocartilaginous structure are divided bluntly, until the entire nasal skeleton can be clearly observed.

For septoplasty and cartilage harvesting for later grafting a hemi-TI is used. In difficult septoplasties or in asymmetric tips, the interdomal ligament is cut and the medial crura separated. Using a speculum the caudal edge of the septal cartilage is visualized. The subperichondrial plane is established using the tips of pointed scissors or Cottle's elevator and the mucoperichondrium is elevated using sweeping motions. Incisions are made in the cartilaginous septum at 1 cm parallel to the caudal septum and dorsum, leaving in an inverted L-shape support, allowing the maximal amount of cartilage to be harvested. Deviated cartilaginous fragments are disarticulated and removed.

Turbinate surgery further corrects airway obstruction.

Routinely, the author prefers to address the osseocartilaginous vault before the tip and lower third with alar base correction as the last step.

Under direct visualization, reduction of the cartilaginous dorsum is performed with a No. 15 blade, the cartilage is maintained in continuity with the nasal bone. Sharpened Rubin osteotomes are used to resect the bony hump to nasion in continuity with the cartilaginous resection. Initially, a 16-mm osteotome is placed in the 'fish mouth' created by the cartilage resection, then a 14-mm Rubin as the line of resection approaches the narrower naso-frontal angle. In the glabellar area, the hump is sharply separated from the attaching soft tissues, before being removed and preserved together with the harvested cartilage in a physiologic solution. Irregularities are removed with sharp resection to avoid disruption of the osseous-cartilaginous junction.

The dorsum appears to be broadened and the 'open roof' aspect shows through the overlying skin.

Closure of the open roof deformity is through the use of osteotomies, under direct vision using a 3-mm micro-osteotome, creating a laterally fading line for controlled back-fracture created by the lateral osteotomies. Only in broad strong noses are medial osteotomies utilized. If these are especially thick then triangular wedges are removed along the medial osteotomy.

The lines of the lateral osteotomies are low to the face, respecting Webster's triangle and directed towards the highest thin part of the nasal bones. No infiltration, stab incision or periosteal raising is carried out to prepare the lateral osteotomies. The same 3-mm osteotome is

immediately engaged on the pyriform aperture just superior to the inferior turbinate's origin. The osteotome is initially engaged in a plane perpendicular to the pyriform aperture. Once a triangle of bone is preserved at Webster's area, the osteotome is directed up the lateral bony wall under finger control. Just below the level of the medial canthus, the cut is directed more anteriorly to meet the medial osteotomy when required. The back fracture is completed with rotation of the osteotome and finger pressure. The inward fractures can be performed with greater accuracy and precision transcutaneously at the lateral mid portion of the osteotomy and through the glabella if necessary with a 2-mm micro-osteotome and without stab incision.

The mobility of the nasal bones can be palpated through the skin and controlled under direct vision. The dorsum is palpated and visually checked to make sure that no irregularities or projections of bone or cartilage exist. Small bony fragments can be resected with bone scissors and cartilaginous protrusions can be trimmed by blade.

The concept of the open-structure rhinoplasty supports reconstitution of disrupted support mechanisms by suturing and grafting which will resist the effects of scarring and contracture of the soft-tissue envelope. The elevation of the SSTE during rhinoplasty violates a minor support mechanism. Therefore, the medial crura are generally strengthened with a septal cartilage graft or the resected osseocartilaginous hump, sandwiched between them as a supporting strut. A pocket to receive the graft is dissected between the medial crura towards, but not to, the nasal spine. The strut not extending above the ASA is fixated with through and through Vicryl™ 4.0 from the level of the medial footplates. Care is taken not to distort or rotate the nasal tip area by malpositioned sutures. The strut increases support and stability and maintains symmetry of the nasal tip. It can also serve as a foundation for a tip graft.

The medial crural/columellar strut complex is sutured to the caudal septum. This will effectively reconstruct the medial crural–septal ligaments sectioned when a TI is used.

If tip narrowing and upwards TR is desired, cephalic trim of the LLC is performed. Care is taken not to weaken the lateral crura, by leaving a symmetrical strip of cartilage at least 6 mm in width. Over-resection can weaken the lateral legs of the nasal tripod, resulting in external valve collapse on inspiration and retraction of the nostril rim from scar contracture on the LLCs. This is remedied during surgery with alar batten grafts.

The recurvature of the ULC contributing to intercrural width is resected together with the cephalic edge of the LLC. The cartilage is removed while leaving the nasal skin intact at all times.

Aesthetic adjustments to the position of rhinion to create a more natural dorsum are often accomplished using Skoog's technique of replacing the resected dorsal hump after sculpting to the desired shape and size, into the dorsal pocket thereby avoiding irregular edges, asymmetry and the 'open roof deformity'.

Modification of the caudal aspect of the medial crura can be carried out for such abnormalities as a hanging columella deformity.

Opening up an obtuse NFA or widening the root of the nose can be done by cartilaginous grafts.

Debulking of the undersurface of thick sebaceous tissue of the nasal tip is accomplished under direct visualization. Care is taken not to injure the dermis. The effects of debulking the tip skin can be seen in the redraping of the SSTE providing superior tip definition.

A widely arched dome may be narrowed and lowered by excising triangles of LLC cartilage, leaving the skin intact. The free ends of the lateral crura are reconstructed into a continuous strip by suturing the ends with 5/0 resorbable sutures to maintain the strength of the tip tripod. Irregularities can be trimmed. The interdomal ligament is restored by an interdomal mucosal apposition mattress suture, lying just below the domes, acting to restore reattachments between the LLC and the ASA, thus contributing to TS.

A septal cartilage graft sculpted into a three-dimensional shield-like tip lobular graft with bevelled contours is placed over the Stable nasal tip structure. This establishes the desired projection, angle of the infratip region, a double break and the bidomal shape. This graft is usually thickest at its dorsal aspect and gradually tapers to the ventral. Resorbable 5/0 sutures can secure the graft to the underlying septal crural foundation. An elongated tip graft extending along the greater part of the columella is used to provide greater stability for increased projection. In general, this graft is not fixated so, after initial wound closure, it can be displaced to the desired position, creating a more pleasing tip definition.

After careful inspection of the reconstructed skeleton, the skin incisions are meticulously closed with 6/0 nylon sutures. With Rees and Skoog we believe that no amount of post-operative splinting, clamping or other forms of pushing and pulling, nor healing, will provide a better outcome.

The SSTE is taped to the nasal skeleton, especially in the supratip region, thus eliminating dead space. An additional adhesive strip is placed along the nasal tip for support.

A plaster of Paris with forehead extension, avoiding any movement, is used (Tessier). A generous amount of antibiotic ointment is placed in both nares.

A reinforced Silastic™ sheet is used as a septal splint at the right side where functional surgery has been performed. Although through-and-through sutures readapt the mucoperichondrial flaps, nasal packing is frequently used. Unless contraindicated, intraoperative steroids and antibiotics are given routinely. A gauze is taped over the nostrils to function as a drip pad.

The patient receives facial ice packing and a position of at least 45° is advised for up to 24 hours. Antibiotics are given for 3–4 days till the packing is removed. Upon follow-up in 7 days, the splint and the Silastic sheet (s) is removed, as well as the sutures.

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Rhinoplasty for Southeast Asian noses: Open and closed approaches

CORAZON COLLANTES-JOSE, EDUARDO C YAP and KONRAD P AGUILA

CONTENTS

Asia is a big continent and the characteristic noses can be very different from the Middle East to Far East.

This chapter will concentrate its discussion on Southeast Asian noses. The common features of Southeast Asian noses are the following: bulbous tip, thick skin, low dorsum, weak cartilages, short and upturned tip and hanging and wide ala.

Most noses need dorsal augmentation, lengthening, tip projection, columellar show, hanging ala correction and alar base plasty.

DORSUM

The nose can be divided into thirds. The dorsum comprises the nasal bones as the upper third and the dorsal septum with the attached upper cartilages (UCs) as the middle third (see Figure 86.1).

Most aesthetic deformities of the nasal bone are low radix and wide nasal bone base. A low radix can be augmented with soft-tissue material such as fascia or softened cartilage or synthetic material, e.g. silicone or expanded polytetrafluoroethylene (e-PTFE) (popularly known as Gore-Tex). A wide nasal bone can be corrected with medial and lateral osteotomies.

The junction of the upper and middle third of the nose is the rhinion. It corresponds to the dorsal hump. A prominent hump can be corrected by direct trimming of the UC with the dorsal septum and humpectomy of the nasal bones using a chisel or rasp. The majority of humps are cartilaginous.

Internal valve collapse is not common in low dorsum noses because of the wider relationship of the septum and the UCs. In the presence of a caudal deviation of the septum, support grafts, e.g. spreader and septal extension grafts (SEGs), can be used to straighten the deviation. A deviated dorsal septum needs splitting the UC from the septum and reinforcement with spreader graft (see Figure 86.2).

The dorsum for most Southeast Asian noses is low and almost always needs augmentation. Dorsal augmentation is performed after tip projection surgery is completed. The tip projection surgery often utilizes a support system of SEGs. The augmented dorsum is used to blend the new tip with the radix (see Figure 86.3). For noses that have a good tip and need only dorsal augmentation, a silastic implant either an I-shape or an L-shape can be used. It is inserted via a closed approach (bilateral marginal incision). The dissection is sub-SMAS (superficial muscular aponeurotic system) at the UC and lower cartilage, and subperiosteal at the nasal bones. The dissection should just be limited in order to avoid mobility of the silicone implant. The undersurface of the implant should be carved well in a concave manner to allow full surface contact with nasal bones and the UCs. Healing is via fibrous encapsulation. Most silicone implants heal well; however, there are some that heal with capsular contracture after several years needing revision surgery. Silicone is also prone to calcification with time.

e-PTFE, popularly known as Gore-Tex, has gained popularity because of its better aesthetic outcome. It is initially introduced in the market as sheets; however, recently many

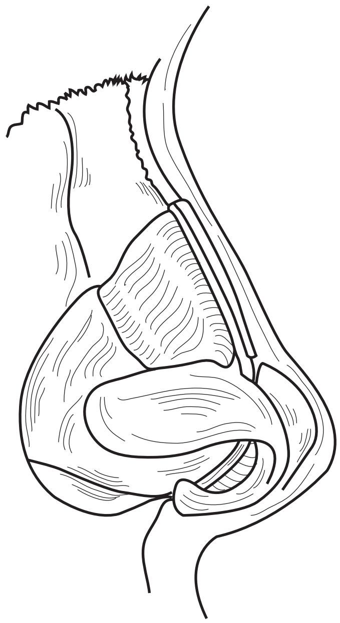

Figure 86.1 Nasal framework.

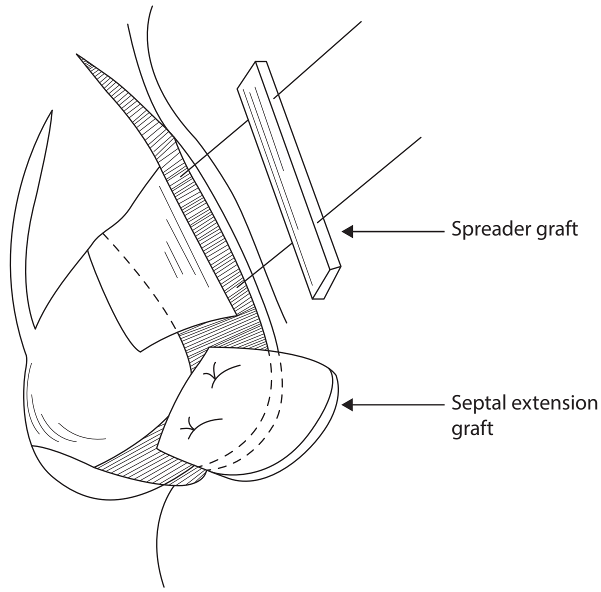

Figure 86.2 Support grafts: Spreader graft and septal extension graft.

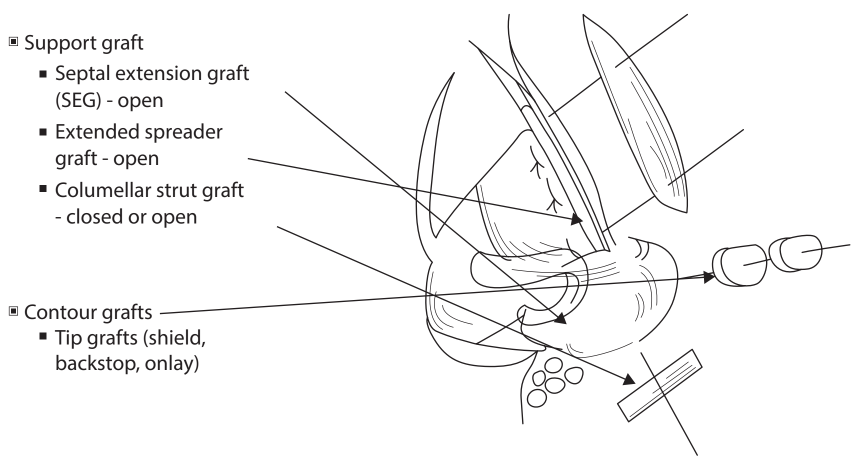

Figure 86.3 Common support and contour grafts.

companies produced preformed e-PTFE of various shapes and sizes. This implant is now preferred because it is more natural looking and heals with tissue adhesion. Despite it being less visible as an implant, there are times that it may show under a thin skin. In order to make e-PTFE implant better looking, the sides of the Gore-Tex should be cut and carved well to avoid cornering appearance (see Figure 86.4). Make certain implant placement is midline and in full contact with undersurface. Since e-PTFE is soft, it is not used in tip support surgery. One dreadful complication of e-PTFE is infection. Infection can be avoided by diligently observing the sterility, e.g. soaking the implant in gentamicin solution when not in use and avoidance of prolonged air exposure. Implant package should be opened only when it is time for insertion. The caudal edges of the implant should be cleared and away from the incision line since the incision wound can be the site of entry of microorganisms (see Figure 86.5).

Cartilage may also be used in dorsal augmentation. Cartilage source may be from the septum, ear or rib. Mostly the source is from the ear. Scoring the cartilage in the concave portions helps make the implant to bend to a straight looking piece; however, sometimes warping can still occur. Resorption and warping are high in cartilage for dorsal augmentation.

Dermofat from the sacrococcygeal area may sometimes be used as augmentation material. The advantage is the natural look, however, resorption is high. This material is usually reserved for secondary rhinoplasty of patients with thin skin.

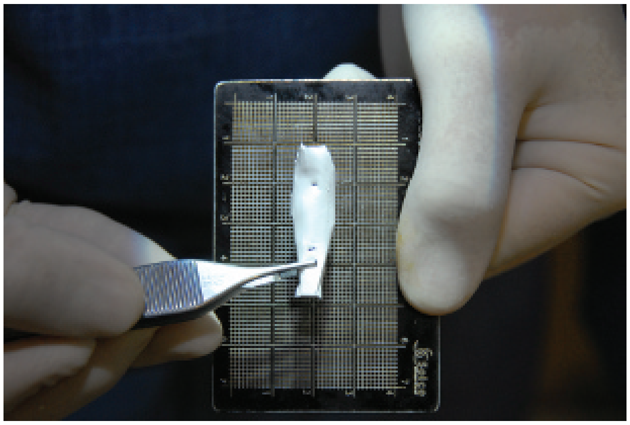

Figure 86.4 e-PTFE 2 layered sheets and shaved tapered at all sides.

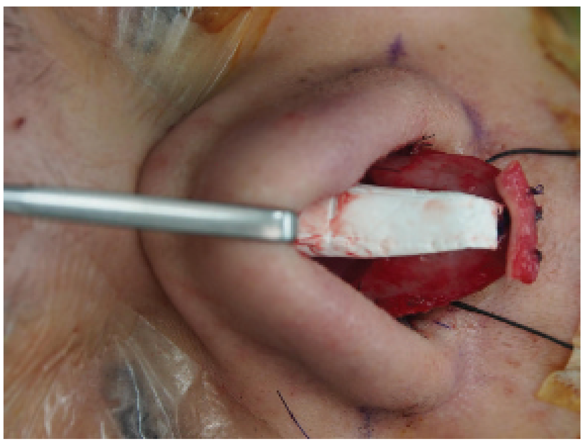

Figure 86.5 e-PTFE implant. Note the caudal edges of the implant are within the line of incision.

Homograft materials such as cartilage and dermis are gaining popularity nowadays because of least reaction; however, the cost is prohibitive.

TIP

Most Asian tips are bulbous which is due to thick skin or convex lower lateral cartilage (LLC), or a combination of both. The dome portion of the lower cartilage may not be well formed too. The medial crura are usually much smaller and weak causing the inadequate tip support.

Many simple procedures such as transdomal and interdomal suture techniques are good enough to define the tip; however, most often, tip grafts such as shield and onlay grafts are needed for a more defined tip. A too convex LLC may need cephalic trimming, making sure that enough 5–8 mm of LLC is left behind for support and patency of external nasal valve.

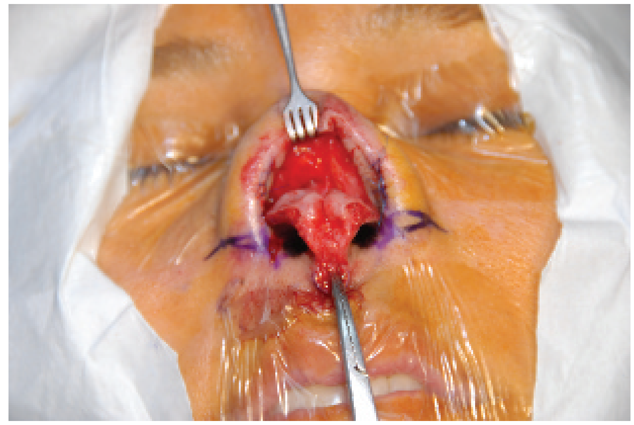

Figure 86.6 New projected position of lower cartilage via fixation to SEG.

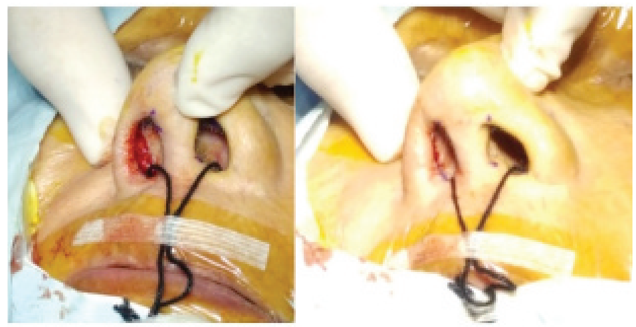

Figure 86.7 A piece of triangular tissue shaped like a 'sail' is excised from the inner lateral portion of the nasal vestibule. The alar rim is rolled in and sutured to close the defect.

The whole shape of the lower cartilage can be changed when the dome is pulled anteriorly and fixed to the anterior angle of SEG for a total new dimension of tip projection. SEG is the usual support graft used for lengthening a short nose and projecting a low tip (see Figure 86.6).

An additional procedure to improve the tip in a thick skin is to perform defatting, especially at the supratip area.

ALAR RIM

The rims in some Asian noses are hanging and need lifting procedure. A triangular tissue is excised at the inner lateral portion of the nasal vestibule. The triangular tissue is shaped like a sail of a sailboat with two irregular sides and a base. The inferior side is the inner rim of the ala, and the cephalic side is a skin groove in the vestibule which is a depression marked by transition of thin and thick vibrissae. The alar rim is then sutured to the inner vestibular skin like a flap (see Figure 86.7). The sail excision is usually done as the first procedure in rhinoplasty in order to allow the maximum flexibility of manoeuvring the ala from marking, incision, excision and suturing.

ALAR BASE

A wide alar base may sometimes improve when tip is projected; however, further narrowing can be achieved by a wedge excision of the sill. The wedge sill excision is a three-dimensional analysis and can be in continuum to the lateral alar groove for correction of alar flare. The incision at the lateral alar area is made 0.5–1.0 mm above the alar groove for better wound healing and coaptation (see Figure 86.8).

TECHNIQUE FOR OPEN STRUCTURAL RHINOPLASTY (OSR)

Depending on the severity of deformity, either closed or open approaches are used. The general rule is the simpler the correction, the simpler the approach.

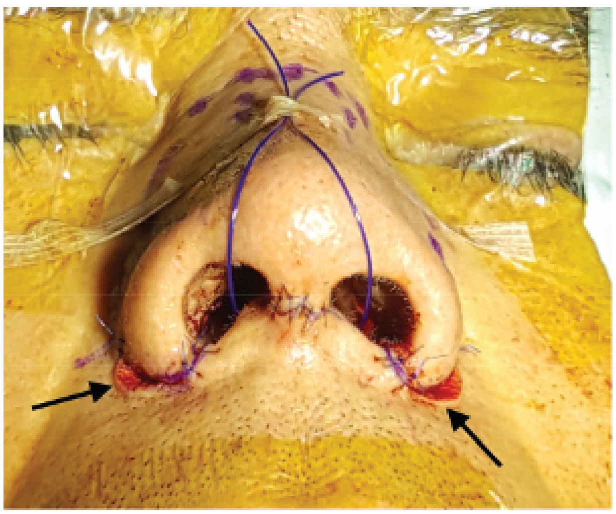

Figure 86.8 Incisions should be made 1 mm above the alar crease for better wound coaptation during suturing.

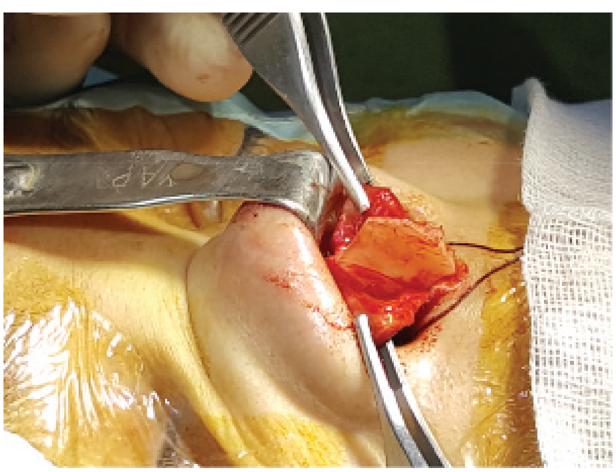

Figure 86.9 Septal extension graft. A piece of cartilage harvested from the central portion is sutured at the caudal strut for added length and height for tip support.

Closed technique is used commonly in noses that need minor surgical manoeuvres such as dorsal augmentation and tip suture with or without grafting. It is also the choice of approach in minor touch-up procedure in secondary rhinoplasty.

Open approach is used when there is a need to explore and repair the cartilaginous structures under direct vision, e.g. crooked nose, asymmetric tips, moderate-to-severe bulbous tip deformity, short noses and cleft lip noses. It is also commonly used in difficult secondary rhinoplasty.

The septum is the most stable structure to hold the tip, so it is the principle of structural rhinoplasty that the lower cartilage is repositioned to a new projection via a support graft, e.g. SEG (see Figure 86.9). Since the septum is small in majority of noses, there is almost always a need to harvest conchal cartilage for tip contour grafts while the central septum harvested is used solely as support graft.

The cut starts as a marginal incision just as one is performing a closed approach rhinoplasty. The cut is along the caudal border of the LLC. The dissection is supraperichondrial in the lower cartilages. At this point, a transcolumellar incision is made to completely access the plane to elevate the skin and soft-tissue envelope (SSTE). The dissection at the lower cartilage and the UC is above the perichondrium whereas the dissection in the nasal bone is beneath the periosteum. The dissection should be wide up to nasomaxillary bone.

Tip definition procedures may be carried out at this time using the domal and interdomal sutures. Depending on the strength of the medial crura, a columellar strut graft and a tip shield or onlay graft can be used. Osteotomy can be performed at this time. If there is a need of a dorsal augmentation, a graft is used in order to blend the bridge with the new tip. The material for dorsal augmentation can be autologous using conchal cartilage or septum, or it can be synthetic using Gore-Tex or silicone. The dorsal augmentation material should be just appropriate in size and shape. Usually implant thickness ranges from 2 to 5 mm. The cephalic end of the implant should blend well with the radix whereas the caudal end should just end at the UC or over the LLC. If the implant caudal end rests on the LLC, the implant end should be sutured to the cartilage for stability (see Figure 86.10).

Figure 86.10 Final appearance of the Gore-Tex dorsal implant and the multiple layered tip grafts for tip definition.

If the tip needs elongation (counter-rotation) or anterior projection, a more structured grafting is needed. This time the membranous septum is dissected using sharp scissors till it reaches the caudal margin of the septum. A subperichondrial dissection is made bilaterally up to the bony portions of the septum. A submucous removal of the central portion of the septal cartilage is performed leaving a 10 mm of caudal and dorsal strut. Any bony spurs are removed using rongeur forceps. The removed cartilage is fashioned into an SEG and is sutured to the caudal strut using PDS 5-0 sutures. The dome of the lower cartilage is sutured to the anterior end of the SEG (see Figure 86.9). The medial crura are also fixed to the SEG for stabilization of the lower cartilage (see Figure 86.3). The mucosa of the membranous septum and the cartilaginous septum is sutured in a quilt manner using vicryl 5-0.

Further tip enhancement can be achieved using a tip shield graft or onlay graft. The dorsum can be augmented this time using autologous cartilage or synthetic implants, e.g. silicone, e-PTFE (Gore-Tex) or Medpor. Most commonly Gore-Tex is used nowadays because it heals by adhesion and not by encapsulation. It also gives a more natural look over silicone. Gore-Tex however is prone to infection if not properly sterilized and handled. It should be opened just before use to prevent long air exposure. It should be soaked in an antibiotic solution, e.g. gentamicin, just before inserting. Fixation sutures should be applied in the caudal end of implant to prevent deviation. Preformed implant should be well carved, especially in the rhinion area, in order to ensure maximal adhesion of the implant to the underlying bone and cartilages (see Figure 86.11). Make sure to fill up any gap in the undersurface of the Gore-Tex with cartilage or a thin sheet of Gore-Tex. This is to prevent collapse of the caudal portion causing supratip depression. The dorsal augmentation should be just enough to blend the new radix to the new tip, making sure the implant is not palpable.

Figure 86.11 The ventral portion of a preformed e-PTFE (Gore-Tex) should be well carved in order to avoid mobility of implant post op because of the cantilever-fulcrum at the rhinion. Carving the ventral side ensures maximal contact of implant with the bones and cartilages.

A trial closure may be tried and checked for the tip projection. Additional tip grafts may be used if deemed necessary. Closure of the columella is bilayer. The muscle and soft tissue is closed using vicryl 6-0 and the skin is closed using nylon 6-0. The marginal incision in the vestibule is closed using vicryl 6-0.

Palpation is very important aside from the looks immediately post-op. Whatever is the form you see on the operating table is the form the patient will have. Any irregularity should be corrected.

External dressing includes putting on Steri-Strip and a thermal cast for 5–7 days. Sutures are removed in 5–7 days. Oedema may still persist for the next few weeks, but usually the nose is good looking 4–6 weeks post-op. Improvement and wound maturation will gradually improve in 6 months to a year.

AUGMENTATION RHINOPLASTY USING CONCHAL CARTILAGE VIA CLOSED APPROACH

Closed rhinoplasty approach is considered a minimally invasive type of surgery. This approach is commonly utilized for nasal contour enhancement or aesthetic purposes.

Conchal cartilage is the autologous graft of choice used for augmentation rhinoplasty because it is readily accessible. The average thickness of ear cartilage is 1.5 cm and is capable of increasing the height of the nasal dorsum from 3 to 5 cm by suturing 2–3 layers of cartilage together.

The ear cartilage is harvested via posterior auricular incision. This will give the surgeon a better surgical field to harvest the whole conchal cartilage, i.e. the cymba and cavum concha as a single piece (see Figure 86.12). To prevent deformity of the pinna, a 5-mm margin along the antihelix, antitragus and inferior crura should be preserved. This serves as the framework of the external ear. The incision is then closed via interrupted or simple continuous suture using nylon or prolene 5-0. The contour of the concha is preserved using two peanut cotton balls serving as splinting device in the concavity, which is then kept in place by surgical tape.

Figure 86.12 Conchal cartilage is harvested via posterior auricular approach.

To design the nasal graft, a spindle-shaped portion is cut from the harvested cartilage to form the first part of the graft (see Figure 86.13). The length of the spindle-shaped cartilage is based on the measured length of the nasal bone with a width of 8 mm. From the longest portion of the remaining harvested cartilage, another straight piece with 3-mm width is also obtained. The two pieces are sutured together with straight cartilage positioned under the concave side of the spindle-shaped material. This will serve as the frame of the graft. Additional layers are sutured to the graft frame according to the height needed for dorsum augmentation (see Figures 86.14 and 86.15).

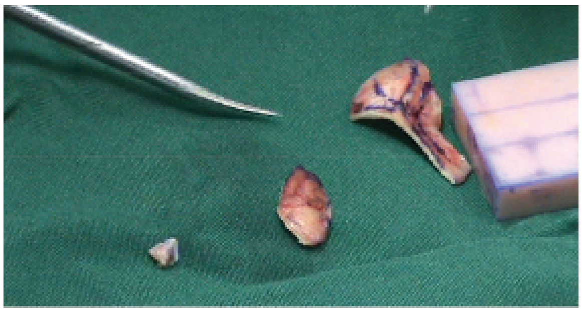

Figure 86.13 A spindle shaped portion is obtained from the harvested cartilage.

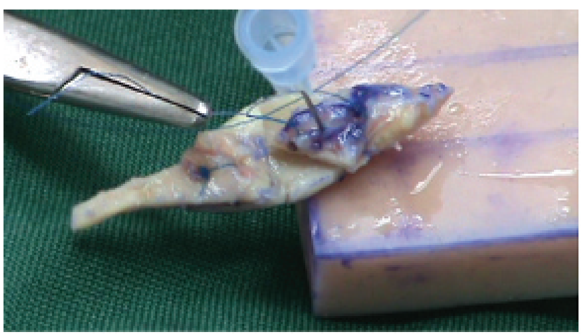

Figure 86.14 The pieces of cartilages are sutured together to fabricate the dorsal onlay graft.

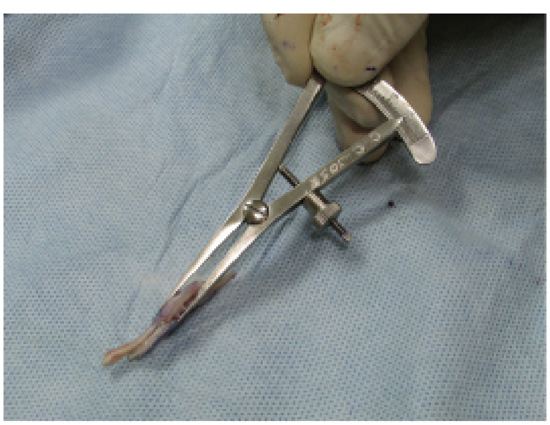

Figure 86.15 Picture showing 3 layers of cartilage to obtain 5 mm thickness.

Figure 86.16 Schematic diagram showing how the conchal cartilage fits inside the nose for augmentation.

For nasal augmentation, a marginal or infracartilaginous incision is done. Unlike in open columellar approach, there is no transcolumellar incision done and the columella is preserved. Dissection is done along the suprachondrial plane of the LLC and the upper lateral cartilage. Upon reaching the rhinion, the dissection is carried down to the subperiosteal plane of the nasal bone area. As much as possible, the width of the dissection should be limited to 1 cm. It should be straight, midline and free of soft-tissue webs. The fabricated cartilage implant is inserted as dorsal onlay graft. Additional height of the graft may be achieved by inserting a piece of cartilage underneath the graft (see Figure 86.16).

For tip augmentation, an interdomal suture is performed to strengthen the tip or the dome of the LLC that will serve as the base for the tip graft. A single or double layer of shield graft is inserted to define the tip and add projection. A columellar strut graft may be inserted to achieve rotation of the tip if desired. The incision is then closed and an external splint is applied to keep the graft in place.

Closed rhinoplasty approach is effective in improving the height and appearance of an oriental nose. This minimally invasive procedure allows the surgeon to perform the surgery under local anaesthesia and may be performed as an ambulatory minor surgical procedure.

Top tips

- Always ensure that your patient's expectations are realistic.
- When using an implant to augment contour, the soft-tissue pocket should be just enough to accommodate the implant to prevent its later migration.
- When using augmentation materials, always discuss their nature with the patient. Some patients will have religious or cultural objections to some materials.

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Post-traumatic rhinoplasty

LUC CESTELEYN

CONTENTS

PRINCIPLES, JUSTIFICATION AND INDICATIONS

Post-traumatic deformities

Nasal trauma is the most frequent facial injury, usually resulting from vehicle accidents and interpersonal violence.

In many cases, functional airway obstruction and external deformities make the patient seek treatment.

The post-traumatic situation creates a significant disharmony of proportion: twisted and angulated noses upset the flowing line from the supraorbital rim to the tip of the nose, as does an avulsed or depressed upper lateral cartilage (ULC), a deviated dorsal cartilaginous septum or an asymmetric alar–cartilage complex.

Those patients who sustain sufficient nasal trauma and require relatively acute nasal reconstruction and rhinoplasty compose a different category of patients presenting for nasal cosmetic surgery. Many would have never considered surgery if acute trauma had not produced a deformity or an airway insufficiency. Their motivations are often different from the patient troubled by a long-standing nasal deformity, since they essentially wish the nose be restored to its former pre-injury appearance and function. Others will wish to correct a pre-existing deformity under the justification of the recent nasal injury. Generally, trauma patients are clearly well-motivated as a result of the nasal injury.

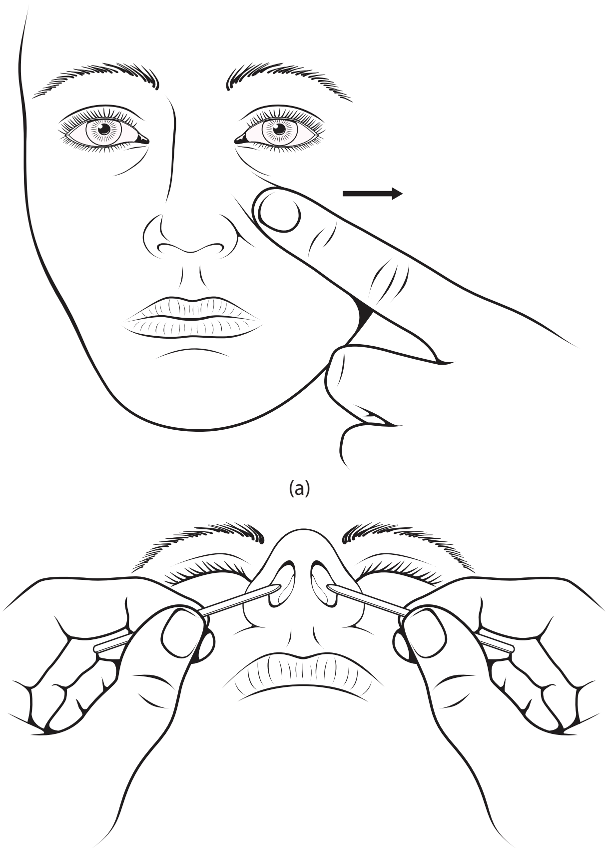
EXAMINATION

Inspection and photographic documentation should pay special attention to external deviation and contour deformities. Even more important than assessing objective criteria, which are utilized in profile planning, is the study of standardized photographs, since the aesthetic appearance predominates.

The width of nose and the alar base should be compared with the intercanthal distance: in noses with traumatically lowered dorsum, an illusion of widening must be corrected. Manual palpation is necessary for the position and symmetry of the bones, dorsal projection and the superior septal angle. Palpation of the caudal septum and tip cartilages can yield valuable information regarding the underlying deformities or deviations.

The rhinoscope is necessary for inspection of the nasal mucosae, the septum, the turbinates and the nasal valve. External deformations should be correlated with internal changes of the bony-cartilaginous septum and the lateral sidewalls with the effect on the nasal tip. Airway evaluation calls for anterior rhinoscopy before and after vasoconstrictive shrinkage, palpation of subtle abnormalities of the septal cartilage, anterior nasal septum (ANS) and floor of the nose.

Transillumination of the septum allows assessment of trauma and residual cartilage in operated noses.



(a)

(b)

Figure 87.1 Airway examination: (a) Cottle test and (b) Cotton-tip applicator technique.

Cephalometric and lateral 'soft tissue' RX examination is used to measure tip rotation (TR) (by the naso labial angle [NLA]) and tip projection (TP) (by angle sella-nasion and sellion to tip). The nasofrontal angle (125°–135°) and the columella lobular angle (CLA) or 'double break' (45°) should also be measured on lateral cephalograms.

We found the Cottle test and the cotton-tip applicator technique useful (Figure 87.1a and b). By pulling the cheek laterally, the contribution of the vestibular portion (nostril, upper lateral cartilage (ULC) and alar rim) of the valve to airway obstruction can be tested. If there is a positive response to the cotton-tip applicator lifting the caudal end of the ULC, the indication for spreader grafting is obvious; similarly lifting of the lower lateral cartilage (LLC) can diagnose alar collapse with the indication for alar reinforcement by batton or lateral crural grafts.

OPERATION

Post-traumatic nasal reconstruction

Primary post-traumatic surgery is limited to symptomatic treatment of haemorrhage and reduction of major dislocations. In general, the reconstruction is planned 6–12 months after the injury or the primary repair, at the time of maturation of scar tissue and stable deformity.

After blunt trauma, a twisted saddle deformity with broad and flattened pyramid and loss of septal height with columellar retraction and acute NLA must be corrected. The open approach is preferred, but sometimes a direct or endonasal approach in combination with a transoral access to a displaced ANS and caudal septum are chosen.

SADDLE NOSE DEFORMITY

Saddle nose deformity is the most common sequelae of direct nasal injury with displacement of fractured nasal bones and cartilage into the pyriform aperture, rarely as a result of loss of tissue, or unrecognized septal haematoma. For correction, only homologous material is used (Figure 87.2a through c). Septal cartilage, stacked or layered, is the material of choice for dorsal onlay. Septal bone from the maxillary crest and the vomer can be used in the deep layers. Autografts of bone or cartilage from the nose seem to survive almost *in toto* in contrast with iliac bone or costal cartilage. If not available in quality or quantity, conchal ear cartilage is used. Dorsal graft of rolled ear cartilage filled with scarps of cartilage and bone have been used successfully. For severe deformities, we tend to use reliable calvarial bone, covered with cartilage and/or temporoparietal fascia, harvested through the same hemicoronal approach. In total collapse, a bony strut is fixed in or at the ANS to support a dorsal graft fixated in or at the glabella. Iliac bone grafts are rarely used by us because of the morbidity, the second operation field and variable resorption over time. Exceptionally, in young children, rib-cartilage is used because harvesting of unicortical calvarial bone is problematic and resection on the septum condemned. Ideally, the grafts should be placed in a subperiosteal pocket at the cephalic dorsum and underneath the tip cartilages at the caudal end. To prevent pointed tips they should be onlay grafted. In total reconstructions, the glabellar region and the lateral walls have to be grafted: crushed cartilage, plumping bony fragments and thin bone plates are useful.

SEPTAL DEFORMITY

Major septal deviations, from trauma, sometimes an occult injury in childhood, and usually in combination with deviated pyramids and compensatory hypertrophic inferior turbinates, cause functional airway obstruction with mild symptoms to obstructive sleep apnoea. Septal deviation can cause major asymmetry of the cartilaginous vault and the tip, creating a tension tip. Therefore, a septoplasty must be performed with the rhinoplasty (usually before), which by narrowing the airway can

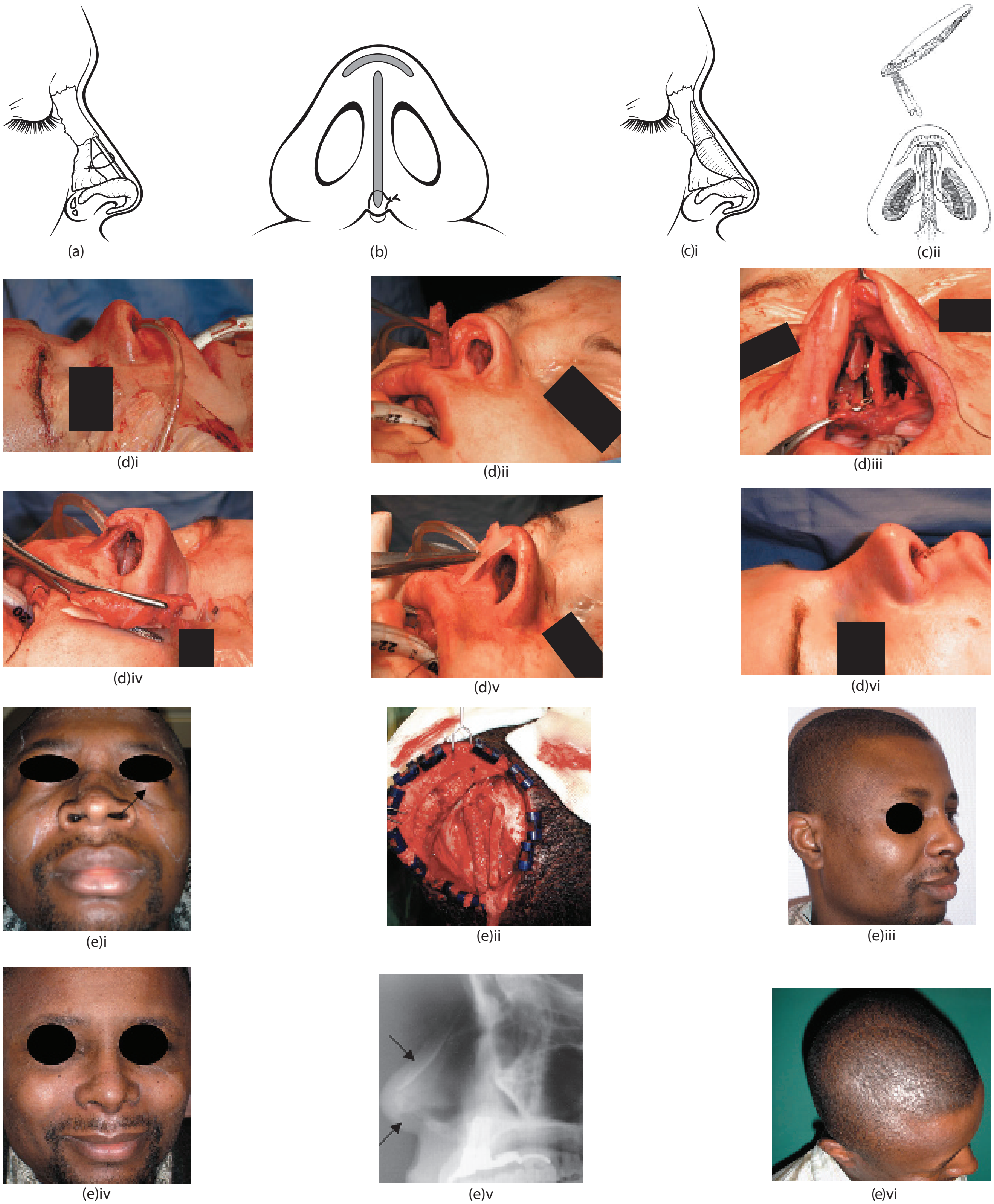
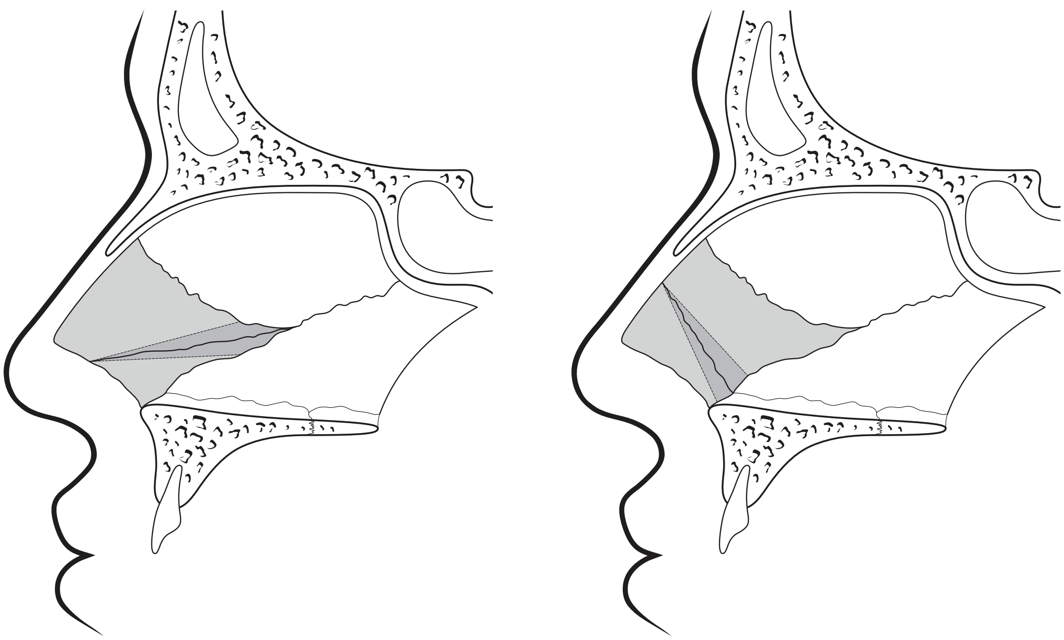


Figure 87.2 (a) Cartilaginous grafts (sutured together or not) for depression of cartilaginous dorsum. (b) (Osseo) cartilaginous grafts for dorsal augmentation or camouflaging a deviation by asymmetrical placing. (c) Bony grafts can be wired at the ANS in total loss of tip support, for prevention of pinching tip onlay grafts are used. (d) Bone grafts to reconstruct severe saddling: subperiosteally at the nasal bones, below the sutured domes at the tip. Important saddle corrected by osteosynthesized osseous strut on the ANS, dorsal layered calvareal bone graft covered with temporoparietal fascia and modified long tip-columellar graft. (e) Early post-traumatic septorhinoplasty for total nasal destruction, septal collapse, saddle deformity and loss of tip support with calvarial bone grafts for tip support and covered with fascia grafts for dorsal reconstruction, the bone grafts in post-operative radiography and the residual coronal scar.

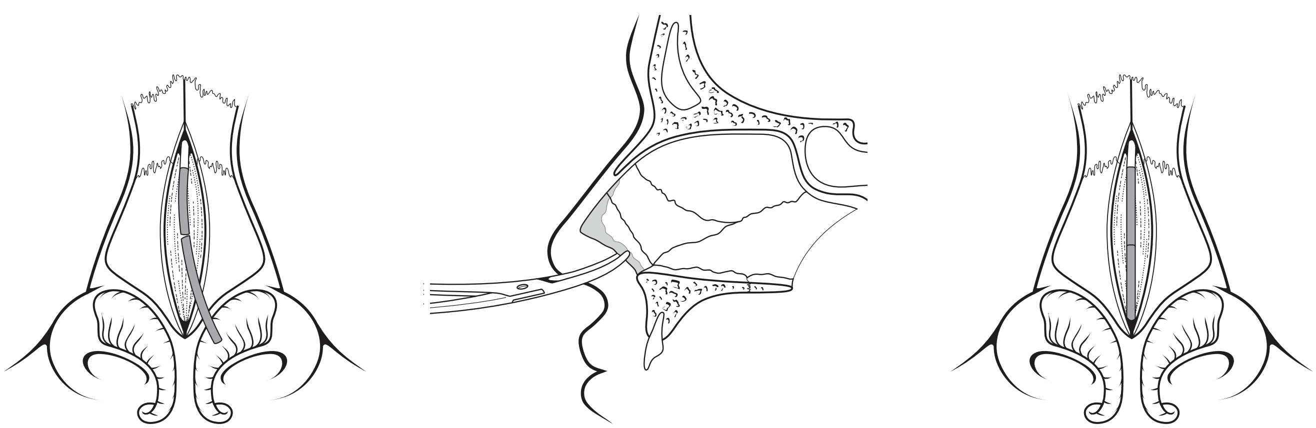
cause decompensation of marginal airway problems due to deflections or septal thickening in the valve area. If hump resection is needed it should be osteotomized as a monobloc, if necessary asymmetrically, immediately after the extramucosal dissection, permitting a better dorsal access to the septal deformity and saving a one-piece hump for repositioning or as a grafting material.

If there is no need for bridge reduction, the ULCs are sectioned at the junction with the septum. After the lateral osteotomies, a medial osteotomy frees the osteocartilaginous flaps and permits luxation of the bony septum to the midline. High deviations may cause recurrent pyramidal deviation as the roof is uncapped by lowering the dorsum; in such noses lateral and sometimes also an intermediate, osteotomy is indispensable. In 'tension' tips, the septoplasty will release the tip and influence its position. Accordingly, the septoplasty should be performed before the tip-plasty, and total septorhinoplastic reconstruction is necessary to improve the nasal airway and maintain long-term success of the rhinoplasty.

Cartilaginous septal deflections result from traumatic fracture lines, creating angulations up to 90° and spurs. Vertical, oblique or horizontal septal angulations, the sites of old fractures, may be excised with conservative wedges, removing a small amount of normal adjacent cartilage or bone. The remaining cartilage is left attached to the contralateral mucoperichondrium for strength and support after realignment by suturing through an endonasal approach (Figure 87.3a).



(a)



(b)

Figure 87.3 Septal surgery. (a) Excision of septal angulation at old fracture sites through endonasal approach. (b) 'Swinging-Door' technique to reposition lower septum. If bony septum is straight after sectioning of septum at point of maximal deviation. Disarticulation at the osseocartilaginous junction. Freeing the septum along the floor of the nose and swinging it to the midline with the opposing lining intact.

In marked angulations of the septum, responsible for external deformations at the middle third, the columella and the aesthetic aspect of the NLA, as saddling of the middle third in case of loss of height (horizontal fractures) and columellar retraction in case of loss of length (vertical fractures), an open approach is preferred.

Vertical fractures may create a lateral deviation of the nose and may be associated with a bulbous ULC impacted between the septum and the pyriform aperture, as well as with a lowering of the nostril sill.

Horizontal angulations perpendicular to the anterior crest will create a saddle deformity of the middle vault, which cannot be treated with dorsal augmentation, leaving the airway obstruction untouched; the total height of the septum has to be restored (Figure 87.3b). Fractures with combined angulations can result in an impaction of the dorsum on the cranioanterior part of the inferior turbinate. The ULC can be carried with the deviated septum.

Through the open approach, L-strut fractures or multiple incisions for straightening can be bridged or reinforced with cartilaginous or thin bony grafts to straighten and strengthen the crooked portions of dorsal or caudal septum.

Total endomucosal excision of the cartilaginous septum and replacement as a straightened free graft, if needed, with additional support by grafts can be carried out; according to Rees, follow-up did not reveal chondromalacia in cases of bony/cartilaginous septal reconstruction.

Complications

- Septal haematomas and infection.
- Cerebrospinal fluid (CSF) leak, due to disturbance of the cribriform plate after high osteotomy of a deviated bony septum.
- Septal perforations with symptoms, for example whistling or crusting and epistaxis can theoretically be repaired by sliding mucosal flaps advanced anteriorly and posteriorly on the ipsi- and contralateral side. Inadequate blood supply and scarred host bed can lead to recurrence or larger perforations. The authors always prefer a more reliable closure with a horizontal myomucosal flap derived from the undersurface of the upper lip that can be performed with minimal discomfort to the patient (Figure 87.4).

TWISTED NOSE

A significant post-traumatic deviation of the external pyramid is practically always accompanied by a deviated septum. After septoplasty, correction of the deviated bony pyramid through an open technique with modified osteotomies: narrowing broad or asymmetric noses can be performed with a combination of medial, intermediate and low lateral osteotomies, and camouflage grafting. A sequential osteotomy technique begins with an intermediate osteotomy on the long side (1) sequentially classic lateral (2) and fading medial osteotomy (3) on the long side, and medial (4) and lateral osteotomies (5) on the short side with full mobilization of the bony fragments to reform the pyramid in the midline (Figure 87.5a and b).

Visual correction can be accomplished by asymmetrical shaping of the dorsal hump and inward fractures in the absence of high septal deviation. Eventually this can be lowered together with that portion of the cartilaginous septum associated with the ULC, so that upon infracture, the dorsal border of the nose lies in the midline.

Osteotomies are transcutaneously performed with a 2-mm micro-osteotome and without stab incision or any subperiosteal elevation. Endonasal osteotomies are more aggressive and disrupt the soft tissues more, are less precise and may dive into an undesired path of an old fracture site with possible shattering of the lateral nasal wall. Webster's triangle and the triangular bone at the pyriform rim cranial to the inferior turbinate are respected to prevent airway impingement. Spontaneous back-fractures can occur in previously fractured, sometimes thickened, bony structures. To control such occurrences and to prevent 'rocker' formation, transcutaneous superomedial and superolateral osteotomies are performed through the glabellar region. The same route is followed for the

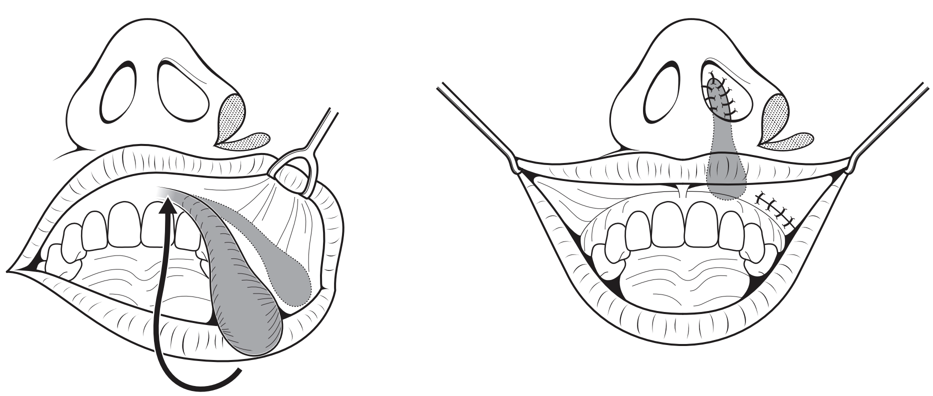


Figure 87.4 Septal perforation. Closure of septal perforations: myomucosal vestibular lip flap.

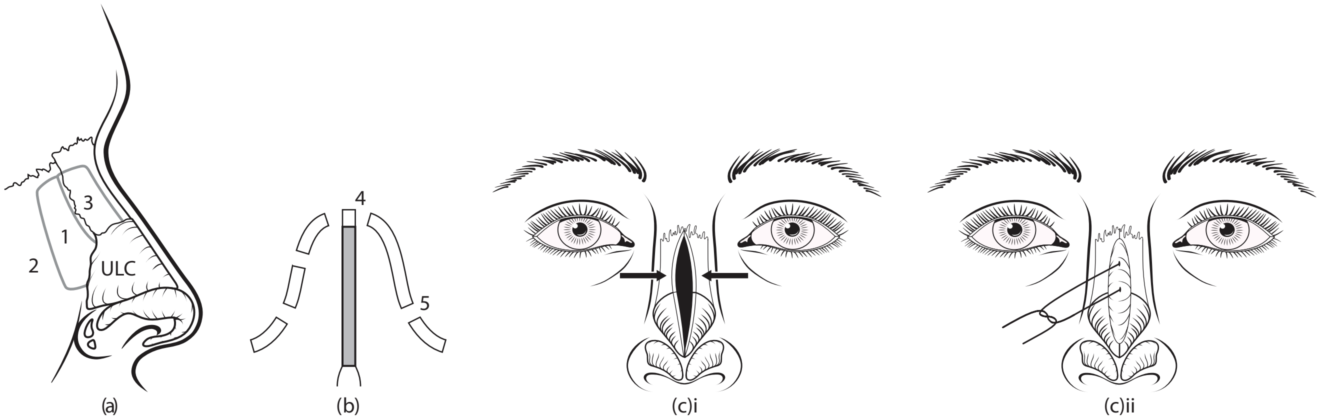


Figure 87.5 Correction of twisted nose. (a and b) Sequential osteotomy technique: intermediate osteotomy on the long side (1) and sequential classic lateral (2) and medial (3) on the long side and medial (4) and lateral osteotomies (5) with full mobilization of the bony fragments. (c)i Crooked noses with dorsal deviations uncorrectable by standard rhinoplasty are treated with camouflaging techniques including (c)ii dorsal septal grafting.

mobilizing osteotomy of a deviated perpendicular plate of the ethmoid, a possible reason for persistent deviation.

Deviations of the dorsum that are uncorrectable by standard approaches can often be camouflaged by various techniques such as septal and ULC overlap and grafts of nasal septum, which are beyond the scope of this chapter. Camouflaging an imperfectly straightened nose can be carried out with autografts removed during the septorhinoplasty. They can mask a high septal deviation or augment a depressed area on one side by insertion off-centre to improve the contour (Figure 87.5c).

In conclusion, the author strongly believes that the best results over time are obtained by the open approach and that lateral osteotomies are virtually always necessary for complete mobilization of the nasal bones and avoiding post-operative 'drift'. The osteotomies must be performed transcutaneously with a micro-osteotome without periosteal undermining for preservation of periosteal attachment and a supportive sling or internal splint for the mobile bones avoiding collapse into the pyriform aperture. Particularly in twisted noses, a Webster's triangle should be respected with preservation of a triangle of bone not being narrowed and remaining lateral along the floor of the nose, thus preserving the full airway which is vital for patient comfort. Remembering the importance of camouflage grafting and strive for a high dorsum and a super strong tip, autografts of cartilage, bone and fascia grafts are primordial to improve the overall aesthetic outcome.

NASAL AIRWAY OBSTRUCTION

After confirmation of the patient's complaint of nasal obstruction, functional tests (Cottle manoeuvre and cotton-tip applicator test) before and after vasoconstriction, CT scan and inspection can diagnose the obstruction.

Collapse of the middle vault

Evidenced by a pinched middle vault or oblique furrow, confirmed by a positive cotton-tip applicator test at the caudal end of the ULC, can be corrected with spreader grafts. Through the open approach, a thick septal graft is harvested at the maxillary crest. The graft should be at least 15 mm by 2 mm to fit passively in an intramucosal pocket between the septum and the ULC from the rhinion to the caudomedial end of the ULC. The graft opens the nasal valve angle by moving the ULC away from the septum and decreases the resistance to nasal breathing. In bilateral cases, the grafts can cause a broadening of the dorsum, which can be camouflaged by augmentation grafting of the dorsum, lifting the skin/soft-tissue envelope (SSTE) and further opening the valve.

Pinching can aesthetically be corrected by onlay grafting of crushed or morselized cartilage or by thin bone plates, acting as a batten being supported by the nasal bones.

In cases of ULC-valve collapse with a horizontal deformity of the lateral wall due to disruption of the osseocartilaginous junction, a thin bony septal graft can be placed from a subperiosteal pocket of the nasal bone to underneath the ULC through an intercartilaginous incision after extramucosal dissection (Figure 87.6a and b).

Airway narrowing at the alar margin

Cartilage buckling and fracture with concomitant airway narrowing at the alar margin, due to blunt trauma, can be corrected by batten grafts from the ear, placed with the concave side down. If simultaneous alar retraction is present, composite chondrocutaneous grafts are needed. These grafts are usually harvested from the contralateral cymba concha, because of approximating shape, with the skin component oversized to allow for contraction (Figure 87.7).

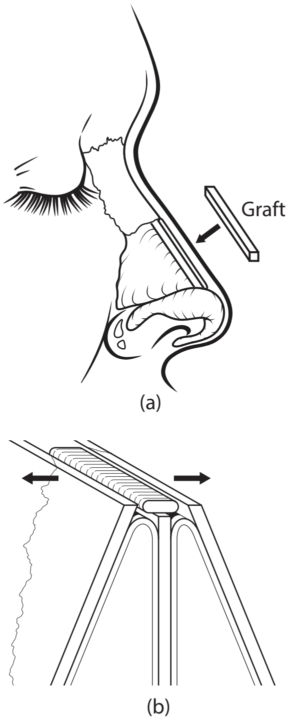


Figure 87.6 Correction of valve collapse – nasal obstruction: Spreader graft placed intramucosally through an open approach; in bilateral collapse two separate spreader grafts can be placed, or one broader graft can be used as an 'inlay' between the ULC (Sheen's spreader technique to correct a collapse of the middle third of the nose).

Inferior turbinate hypertrophy

Hypertrophic inferior turbinates, commonly on the concave side of the septal deviation, may cause airway obstruction and may interfere with septal repositioning. Outfracturing and lateralizing with a Boise instrument can be a conservative therapy in noses with large inferior meatus. Additional conservative submucosal bony resection, mostly of the anterior part, can be performed through an incision along the length of the turbinate and submucoperiosteal elevation of the soft tissue. The redundant soft tissue is resected after redraping.

Our personal preference is resection of the anterior part after infracture with a Cottle's elevator. Articulated scissors are placed above the anterior tip of the turbinate and angled inferior and posterior at 45°. The cut is through mucosa and bone. With the exception of mulberriform degeneration, the posterior part of the turbinate is left untouched (Figure 87.8).

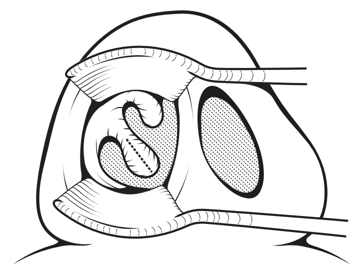


Figure 87.8 Resection of inferior turbinate: Submucous conservative resection.

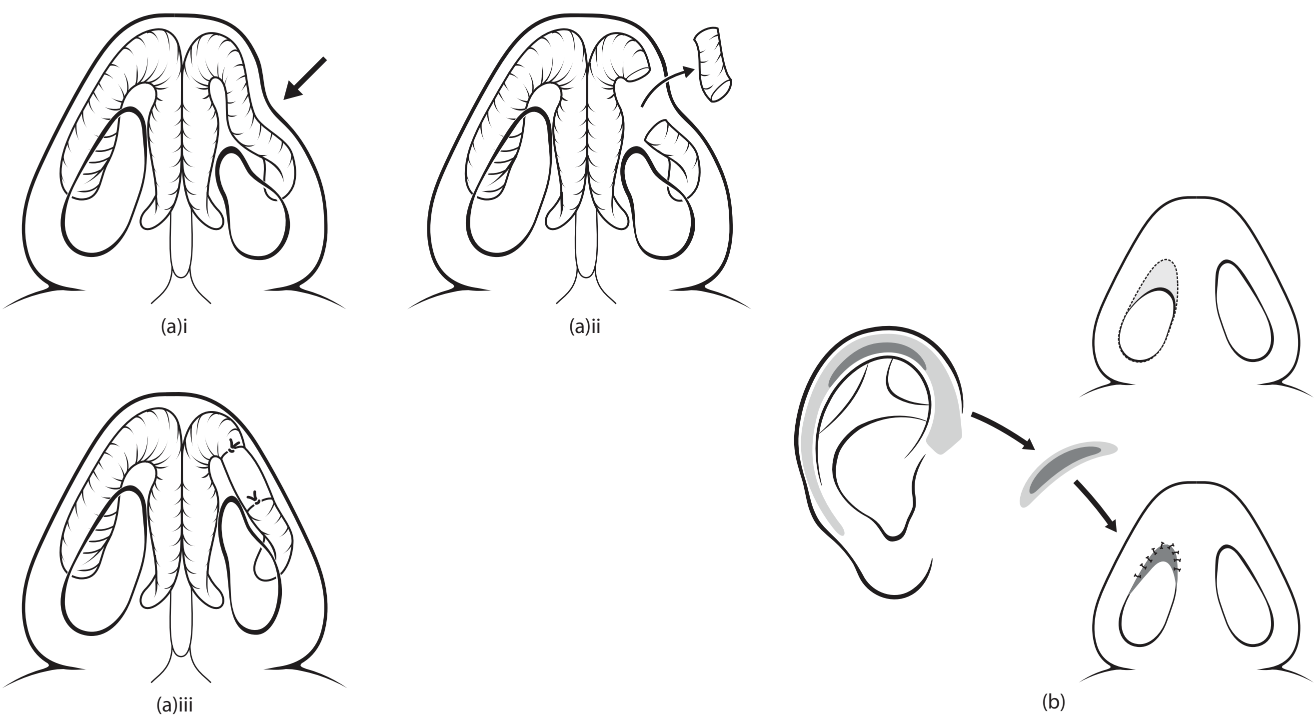


Figure 87.7 Alar collapse – nasal obstruction resulting from (a)i abnormal LC and corrected with (a)(ii and iii) cartilaginous grafts from the ear as batten grafts for abnormal LC. (b) Chondrocutaneous graft for alar retraction with soft tissue deficiency and correction/expansion of collapsed/scarred lateral vestibular wall (composite graft from inner side of crus helicis).

POST-OPERATIVE CARE IN COMBINED SEPTOPLASTY – TURBINATE SURGERY: SEPTAL SPLINTING – NASAL PACKING

Although continuous suturing of the septum provides stability, we believe supplemental intranasal splinting is useful with extensive surgery in post-traumatic septal collapse. Soft 1-mm thick reinforced Silastic sheets (Dow Corning, Midland, MI) cut to line the septum, are always placed at both sides of the septum for 1 week, allowing the mucoperichondrial septal flaps to remain reapproximated in the midline, protecting lacerations and avoiding adhesions or synechiae. Nasal packing with Merocel™ (laminated nasal dressing, Medtronic Xomed, Jacksonville, FL) in antibiotic ointment, in slight over-correction of the former septal deviation, support the Silastic and prevent dorsal collapse. Antibiotic prophylaxis is preferred during the period (3–5 days) of routine nasal packing. After removal of the septal splints, routinely at day 7, but sometimes longer if the epithelial surfaces are not yet healed and synechiae formation should be prevented, the patient is advised to 'mechanically' apply ointments for several weeks post-operatively to prevent crusting and adhesions and to support the recuperation of the mucosae.

SOFT-TISSUE DEFICIENCY

Replacing traumatic loss of soft tissues or loss of total fragments of the nose calls for local flaps. The median forehead flap is the workhorse, sometimes in combination with nasolabial and advancement flaps, but this will not be discussed in this chapter.

Top tips

- Create high smooth dorsum and over-supported tip.
- Harvest calvarial bone, fascia grafts and conchal cartilage.
- Open technique respecting integrity of the SSTE.
- Transcutaneous atraumatic micro-osteotomies for precision.
- Minimal resectioning, realistic repositioning and camouflage grafting.
- Reconstruct airway by septal and valve reconstruction, splinting and tamponade.
- Alar base surgery with alar cinch and perialar readaptation on ANS.
- Plaster of Paris with forehead extension for immobilization.

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Laser skin resurfacing

NAVIN VIG

CONTENTS

INTRODUCTION

Interest in skin rejuvenation has seen a marked increase over the past few decades. Whereas ptotic facial tissue may demand a rhytidectomy or blepharoplasty, signs of sun damage (photodamage), scarring and hyperpigmentation can be treated relatively effectively with skin resurfacing. Treatments available include topical retinoids and chemical peels, dermabrasion and laser resurfacing. Of these, laser skin resurfacing offers the patient the greatest, often dramatic, clinical improvement and new technology has increased its availability and acceptability.

GENERAL PRINCIPLES

Ageing and photodamage change the skin in a number of ways. It becomes drier, thinner and less elastic. Rhytides (wrinkles), pigmentary dyschromias, lentigines and actinic keratoses are more visible. At the cellular level, atypical cells are seen in the epidermis, dermal collagen fibres are thinner, less ordered and fibrotic and total collagen volume falls. Elastic fibres fragment and degenerate and dermal vascularity diminishes.

Changes due to photodamage are largely limited to the epidermis and upper dermis, rendering them amenable to laser skin resurfacing. This process uses laser light to remove, or modify, damaged outer layers of skin to stimulate epidermal re-epithelialization and dermal neocollagenosis. Following treatment, healthy epidermal cells migrate from nearby pilosebaceous units to replace atypical cells and new, compact dermal collagen replaces disordered elastotic material. The result is tighter, younger looking skin.

Controlled thermal injury of the skin triggers this regeneration. In a process known as *selective photothermolysis*, lasers specifically target intracellular water, one of four potential targets, or chromophores (others being collagen, melanin and haemoglobin). Each chromophore preferentially absorbs laser light of a certain wavelength allowing thermal injury to be restricted to a site where that chromophore is present. When applied, laser light is absorbed by water in superficial skin cells, causing vaporization, thermal damage and subsequent dermal remodelling.

There are two broad categories of laser used in resurfacing, the ablative and non-ablative, each of which can be traditional (non-fractional) or fractional. The traditional

ablative laser vaporizes away all tissue down to the papillary dermis. Although regarded as the gold standard, it is the most aggressive, and potentially complicated, resurfacing technique.

Non-ablative laser resurfacing (NALR) sits at the other end of the spectrum. These lasers selectively injure the dermis to stimulate dermal neocollagenosis but leave the epidermis intact. Recovery period is short but cosmetic improvements are more modest.

Developed to overcome the risk profile of ablative lasers, fractional laser resurfacing combines elements of ablative and non-ablative resurfacing. It is based upon the concept of *fractional photothermolysis* (FP). Fractional lasers produce narrow beams of high-energy light to create evenly spaced columns of thermal injury to trigger regeneration sparing the majority of the skin. They can be non-ablative (non-ablative fractional resurfacing, NAFR) or ablative (ablative fractional laser resurfacing, AFLR).

CHOICE OF LASER

This is guided by clinical indications, patient age and expectations and operator experience.

In general, patients over the age of 50 with more advanced signs of photodamage will experience the greatest cosmetic improvement after ALR. However, the post-operative course is long, demanding and potentially complicated. They should understand the implications of this before undertaking treatment. It is also less suitable for those with darker skin (Fitzpatrick IV–VI) and on non-facial such as the neck and chest skin. The lack of pilosebaceous units increases the risk of adverse events.

If the patient is unwilling to tolerate the prolonged downtime and risks of ALR treatment, the best alternative is fractional treatment. Outcomes are very good and patients prefer the shorter, less complicated recovery period. NALR is more appropriate for those under 50 with fine rhytides and early photodamage. Treatment can be readily repeated and the recovery period is negligible. NALR can also be used to treat pigmentary and vascular photoaging.

Managing expectations

Whatever treatment is offered, it is critical that patients have realistic expectations of what it is likely to deliver, and understand the potential risks and side effects, at the outset. Those expecting dramatic improvements with non-ablative treatment will find their outcomes unsatisfactory, as will patients expecting every wrinkle to disappear after ALR. Patients deemed poorly prepared or unsuitable for a prolonged recovery period should be dissuaded from ablative treatment.

PRE-OPERATIVE ASSESSMENT

Medical history

A focused medical history is essential prior to any laser resurfacing procedure as certain aspects may render it inappropriate. In addition to a standard history, attention should be paid to the following aspects.

Medical

- History of delayed wound healing or immune deficiency, or medications with this effect.
- Herpes labialis. Previous history increases the risk of reactivation post-treatment.
- Dermatological conditions such as scleroderma, lupus, vitiligo, psoriasis and verrucae. Can worsen after ablative treatment.
- Acne, active or previous, as this may flare-up following treatment.
- Oral retinoids, such as isotretinoin, increase the risk of hypertrophic scar formation post-operatively. Laser resurfacing should be delayed by at least 6–12 months following drug cessation.
- Previous radiotherapy to head and neck increases the risk of scarring.

Surgical

- Previous mechanical or deep-chemical resurfacing. Ablative treatment may unmask hypopigmentation or fibrosis.
- Existing skin fibrosis. Will limit laser efficacy.
- Previous lower blepharoplasty procedures. Infra-orbital ablative resurfacing can increase risk of ectropion.
- Previous face lifts, or grafts. The presence of non-facial skin requires a more conservative approach.
- Tendency for keloid or hypertrophic scar formation. Some laser techniques can increase the risk of scar formation.

CONTRAINDICATIONS

These vary according to the type of treatment offered but include the following aspects.

Absolute

- Active infection: bacterial, viral and fungal
- Active inflammatory or autoimmune facial skin conditions
- Oral retinoids (Roaccutane/isotretinoin) within past 12 months

Relative

- Unrealistic expectations of result
- Inability to comply with post-operative management regime
- Pregnancy or breastfeeding
- History of therapeutic radiation exposure (ablative)

Physical examination

The patient's Fitzpatrick skin phototype should be recorded and high quality pre-operative photographs taken. Key features of photodamaged skin are documented; the presence of scars, keloid or skin lesions should be noted and further characterized if extensive. Suspicious skin lesions should be investigated and managed prior to resurfacing. Eyelid skin elasticity is assessed (scleral show, eyelid snap test and lid lag), particularly important if there is a high risk of ectropion (e.g. previous blepharoplasty, peri-orbital treatment).

PRE-OPERATIVE PREPARATION

Prophylaxis and skin care

There are currently no established consensus-based protocols, and practice varies according to practitioner. However, many advocate the following:

- Oral antiviral prophylaxis, such as aciclovir or famciclovir, is recommended prior to ablative or fractional resurfacing due to the risk of post-operative herpes simplex virus (HSV) infection. It is also recommended for those with a history of HSV infection. Prophylaxis begins 1 day prior to treatment and continues for 7–10 days post-operatively.
- Evidence for the routine use of prophylactic antibiotics is limited. However, they are often prescribed for ablative resurfacing or if there is an increased risk of post-operative infection.
- Many practitioners commence patients on 4% hydroquinone cream for 4 weeks prior to treatment, particularly for those with darker skin types, to limit risk of post-operative hyperpigmentation.

Anaesthesia

Laser resurfacing can be uncomfortable. Topical anaesthetic (e.g. eutectic mixture of local anaesthetics [EMLA]; 1:1 lidocaine 2.5% and prilocaine 2.5%) is applied to the face for 1 hour prior to treatment. Typically, 2 g is applied over 10 cm^2. Local nerve blocks augment this and forced chilled-air devices further minimize discomfort. Some patients may benefit from anxiolytics, or require intravenous sedation or a general anaesthetic.

ABLATIVE LASER RESURFACING

The two main lasers commonly used for ablative resurfacing are the carbon dioxide (CO_2; 10,600 nm) and the erbium:yttrium-aluminium-garnet (Er:YAG; 2,940 nm). Usage of a third, the erbium:yttrium-scandium-gallium-garnet (Er:YSGG; 2,790 nm), is currently limited. ALR is commonly used to treat facial rhytides but can treat coarse skin, minor dyspigmentation and dermatopathologic entities (actinic keratosis, xanthelasma).

CO_2 lasers

Ablative CO_2 lasers can deliver energy in pulses or continuous waves (CW). These are high-energy, short-pulsed (<1 ms) devices or lower energy, scanned-CW devices. The latter use rapid scanning to limit a focused beam to <1 ms skin contact time. This is important in reducing unwanted thermal damage.

Each pulse or scan of the laser delivers fluences (J/cm^2) of 4–5 J/cm^2, sufficient energy for total epidermal and partial dermal vaporization. Each laser pass vaporizes to the depth of 20–50 μm with an underlying area of residual thermal damage (RTD) of 100–200 μm, enough to strongly stimulate dermal collage production. To reduce the risk of inadvertent deeper thermal injury, and subsequent scarring, it is important that numbers of short-pulsed passes over a particular area are limited, or a low overlap setting is used on the scanned-CW device. Energy should be reduced around the eyes, but may be increased around the mouth.

Er:YAG lasers

The Er:YAG laser emits wavelengths at 2,940 nm, and water-containing tissues absorb Er:YAG light 16 times more efficiently than CO_2 lasers. Consequently, much of the energy escapes as steam reducing thermal injury to surrounding tissue. Although this reduces the risk of unwanted effects, it also limits the shrinkage of dermal collagen fibres and haemostasis. Only 1–2 μm of tissue ablation occurs per J/cm^2, so fluences delivering between 5 and 15 J/cm^2 are used according to the area treated. Many more passes may be required to achieve the same degree of ablation as a single pass of the CO_2 laser making this technique more operator sensitive.

CLINICAL IMPROVEMENT

A single treatment session with CO_2 laser is sufficient to deliver significant reduction in rhytides, particularly in the peri-orbital and peri-oral areas, and outcomes are unmatched by other laser technology. However, downtime is long and many patients are often unwilling to undergo

such a demanding and potentially risky procedure. The less significant thermal injury of the Er:YAG laser means a more modest rhytid reduction and skin tightening effect than seen with the CO_2 laser. This makes it more suitable for patients with mild to moderate rhytides.

Side effects and complications

- Erythema usually settles within 1–2 months but may persist for up to 12 months after CO_2 ALR. Flushing may also occur.
- Post-inflammatory hyperpigmentation: occurs in 36% of patients, but up to 80% in those with darker skin.
- Delayed hypopigmentation: unexpected delayed loss of pigment 6–12 months after treatment in 8%–16% of patients.
- Infection: bacterial and fungal infections are uncommon but HSV reactivation in almost 10% of patients.
- Acneiform eruptions: up to 10% of patients.
- Hypertrophic scar: uncommon (<2%) and minimized by sound patient selection and appropriate intra-operative laser technique.

In general, the Er:YAG laser is less uncomfortable and associated with more rapid recovery and fewer adverse events.

NON-ABLATIVE LASER RESURFACING

NALR was developed primarily to overcome the complications of ALR, achieved partially by stimulating the dermis whilst sparing the epidermis. NALR systems allow resurfacing of non-facial skin such as the neck, chest or back, unlike ablative resurfacing, and are also suitable for darker-skinned patients. NALR is suitable for the treatment of mild photodamage, acne scars and dyspigmentation.

Three main groups of non-ablative systems exist, infrared (IR) lasers, visible lasers (pulsed-dye lasers, PDLs) and intense pulsed light (IPL) sources. IR lasers in use are the Nd:YAG (1,320 nm), diode (1,440 nm) and Er:glass (1,540 nm). These systems can deliver between 5 and 40 J/cm^2 to the skin and target the dermis. Epidermal sparing is achieved by concomitant cooling with cryogen spray. PDL (585–595 nm) and IPL (550–1200 nm) both target haemoglobin and are useful in the treatment of telangiectasia and diffuse erythema. The IPL also targets melanin and can be used to treat pigmented lesions and melasma. Approximately 4–6 treatment sessions are required, each given every 2–4 weeks.

Clinical outcome

IR lasers deliver satisfactory outcomes when used to treat fine rhytides and scars. PDL and IPL successfully treat vascularity and pigmentary changes. IPL is often the preferred treatment for rosacea and telangiectasia.

Side effects and complications

The main advantage of NALR is the low risk of complications. Patients usually return to normal activities immediately.

- Post-operative erythema and oedema: usually settles within 24 hours.
- Blistering: uncommon after treatment and associated with inadequate cooling at time of procedure.

FRACTIONAL LASER RESURFACING

The concept behind this approach is to thermally injure a fraction of the skin surface whilst leaving intervening areas of untouched tissue to speed healing and allow deeper laser penetration to stimulate collagen production further. It can be either non-ablative or ablative and is suitable for use on non-facial skin.

NON-ABLATIVE FRACTIONAL RESURFACING

NAFR is suitable for finer rhytides, most scars, textural imperfections, dyspigmentation and melasma.

A number of devices have been approved for NAFR. These are mid-IR lasers (1,440, 1,535, 1,540 and 1,550 nm) and the 1,927-nm thulium laser. NAFR lasers produce 125–250 equally spaced ablated columns, known as microthermal zones (MTZs), per cm^2. Each MTZ is 70–150 µm in diameter and 200–1,000 µm deep. The subsequent dermal injury stimulates neocollagenosis and dermal remodelling. Beyond the MTZs, little thermal damage occurs. The intact stratum corneum acts a biological dressing and thermally injured tissue heals rapidly, supported by spared skin. Eight to twelve passes are usually performed; four to six sessions are normally required at 2–4 week intervals.

Outcomes

NAFR satisfactorily improves the appearance of milder signs of photodamage, melasma and scarring. Only fine rhytides disappear and some argue that this highlights the importance of treating the epidermis more fully to achieve better rhytid reduction.

Side effects and complications

- Erythema and oedema: resolve within 3–4 days.
- Healing is usually complete within 7 days.
- Prolonged hyperpigmentation has been reported in darker skinned patients.

ABLATIVE FRACTIONAL RESURFACING

AFR was developed in an attempt to improve the efficacy of NAFR, combining the concept of FP with tissue ablation. These lasers are often used against rhytides and laxity but perform well against photodamage, most scars, dyspigmentation and melasma.

A variety of devices exist with parameters that can be adjusted according to clinical requirements. AFR lasers vary according to wavelength used (CO_2, Er:YAGG, Er:YSGG), power, microspot size (i.e. laser beam diameter), density and pulse duration. Many of these can be adjusted to alter the effects of treatment. A short, high-energy pulse combined with a small microspot size can penetrate up to 2 mm into tissue, useful for deep rhytides. Conversely, a large microspot size ablates superficial tissue and is useful for treating fine rhytides. Parameters can also be adjusted to minimize recovery times.

Each device interacts with the skin in a slightly different manner but creates well-spaced microscopic columns of ablated tissue, including all epidermal layers, deep into the dermis. Thermal injury stimulates collagen contraction, neocollagenosis and remodelling and molecular alterations similar to those seen in CO_2 ALR are observed. Re-epithelialization is complete within 7 days, facilitated by areas of spared skin.

The number of treatment sessions required depends upon the clinical indication and parameter settings. Normally, one to two sessions are required at 6–12 week intervals.

Outcomes

AFR can significantly improve both fine and deep rhytides, skin texture, lentigines, scars and areas of dyspigmentation. On-going collagen remodelling after treatment mean improvements may take 3–6 months to be fully realized. Overall, AFR outcomes fall just short of those seen after traditional ablative resurfacing.

Side effects and complications

This technique offers a relatively short recovery period (1 week) and a lower risk of developing adverse events compared to ALR, but it is far from complication-free.

- Erythema and oedema: normally settle within 3–6 days
- HSV infection (1%–2%)
- Acneiform eruptions (2%–5%)
- Erythema >1 month (1%)
- Transient hyperpigmentation (<1% Fitzpatrick I and II, 12% Fitzpatrick III and VI)
- Scarring: only reported after neck treatment

POST-OPERATIVE MANAGEMENT

Non-ablative resurfacing

Wound care is minimal. Patients are advised to use a fragrance-free cleanser and moisturizer for 1–2 weeks after treatment, should avoid exfoliating and practice sun avoidance. Patients can return to their regular skin care regime after this period.

Ablative resurfacing

Meticulous wound care is essential to minimize the risk of complications. After traditional ablation, the skin produces large amounts of exudate that must be wiped away regularly as crusting will increase the risk of infection. The face is soaked continuously with wet sponges dipped with very dilute acetic acid solution. A very fine layer of healing ointment or petroleum jelly is applied 3–4 times daily and continues until re-epithelialization is complete (up to 2 weeks). Concomitant use of ice gauze or ice packs and anti-inflammatories can help reduce oedema. After fractional ablation, regular cleaning is also advised but as the majority of the epidermis is intact, there is little exudate. Healing ointment is applied in the same manner for 4–6 days.

After this period, both groups are advised to use fragrance-free cleansers, moisturizers and sunscreen regularly.

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89

Face transplantation

AHMED M HASHEM, BAHAR BASSIRI GHARB and RISAL DJOHAN

CONTENTS

FACE TRANSPLANTATION

Background

Facial transplantation is a major breakthrough in reconstructive surgery offering a solution in complex situations when traditional techniques cannot restore optimum function and aesthetics.

Patient selection

Clinical indications for face transplant procedures have expanded from complex trauma defects to severe facial deformities consequent to neurofibromatosis and vascular malformations (Figure 89.1a through c).

Candidates for such procedure should be assessed in view of the institutional predefined selection criteria, which can vary among institutions (Table 89.1).

Suitable candidates then undergo a detailed and extensive informed consent process, which is followed by a process of organ procurement with a designated organization.[1,2]

Team formation

Success of this complex procedure requires appropriate coordination with multi-disciplinary specialties, such as anaesthesia/intensive care unit (ICU), transplantation, infectious disease, ophthalmology, dentistry, psychiatry, speech pathology, rehabilitation, physical medicine, social work and bioethics. A team coordinator is extremely critical to flawlessly streamline the sophisticated logistics of transplantation.[2]

Donor criteria

Once a brain-dead beating heart donor is found, the matching process can begin. The donor procurement organization approaches donor families ensuring strict confidentiality (Table 89.2).

In contrast to solid organs, face transplantation requires extra matching in terms of age range, ethnicity, gender, skin tone, hair colour and craniofacial skeletal proportions.

If these prove adequate, blood group, and cross match is undertaken to ensure absence of donor-specific antibodies.[1]

TECHNICAL CONSIDERATIONS

Patient preparation

Besides thorough history and physical exam, candidates undergo extensive testing including routine blood work, serum typing and cross-matching, human leukocyte antigen typing, panel-reactive antibody testing, Epstein–Barr virus (EBV) screening, cytomegalovirus (CMV) screening, human immunodeficiency virus (HIV) screening,

Figure 89.1 (a) Frontal view of patient prior to face transplant. World's first near total face transplant, Cleveland Clinic, 2008. Note the midface deformity and tracheostomy dependence. (b) Left lateral view of patient prior to face transplant. Note the midface deformity and tracheostomy dependence. (c) Right lateral view of patient prior to face transplant. Note the midface deformity and tracheostomy dependence. (Courtesy of the Cleveland Clinic.)

Table 89.1 Patient selection criteria

Indications
• Strong desire to proceed with face transplantation • Willing to dedicate 2–4 years towards post-operative rehabilitation • Age between 18- and 60-year old • Minimal coexisting medical illness or trauma • Elapsed injury-to-transplant time >6 months • All pertinent organ systems within normal limits • Displays psychosocial stability according to transplant psychiatry • Deemed acceptable by entire multi-disciplinary face transplant team
Absolute contraindications
• Record of poor medical compliance • Unable to receive immunosuppression after transplantation because of either geographic or financial limitations • Unable to follow strict facial rehabilitation schedule • Geographic limitations precluding close follow-up and monitoring • ASA class 5 • End-stage organ disease • Acquired immunodeficiency syndrome or chronically immunosuppressed • Active cancer (excluding non-melanoma skin cancer) • Complete bilateral blindness • Bilateral upper extremity amputee • Significant psychiatric disorder history • Documented psychological disorder(s) or incomplete psychological clearance preventing transplant psychiatry clearance • Documented history of previous suicide attempt, with unresolved psychiatric condition
Relative contraindications
• Current smoker (>1 pack/day) • Active bacterial, viral or fungal infection • Active hepatitis C infection • CMV status (positive donor and negative recipient) • History/current evidence of alcohol or drug abuse • Type 1 diabetes mellitus • Connective tissue disorder • ASA class 4 • <18-year old • >60-year old • Significant critical organ disease • Remote history of carcinoma (>5 year)

Abbreviations: ASA, American Society of Anesthesiologists; CMV, cytomegalovirus.

hepatitis screening and random cultures (i.e. blood, sputum and urine) evaluating for drug-resistant organisms.

The patient also undergoes a complete dental (to exclude caries/potential tooth abscess) and oro-pharyngeal examination (to exclude carcinoma). Patients older than 50 years

Table 89.2 Donor criteria

Donor inclusion criteria
• Documented brain death with haemodynamic stability
• Minimal amount of medical/surgical comorbidity before death
• Routine laboratory work within normal limits
• Suitable blood/HLA typing
• Negative for EBV
• Negative for CMV
• Negative for human immunodeficiency virus
• Negative viral hepatitis testing
• Acceptable craniofacial radiographic imaging (identify unknown hardware)
• Acceptable facial computed tomographic scan including facial angiography (identify unknown vascular anomalies)
• Acceptable mandible imaging (i.e. Panorex) to rule out dental caries
Donor exclusion criteria
• Congenital craniofacial disorder
• Documented connective tissue disorder
• Facial nerve palsy (unilateral or bilateral)
• History of significant craniofacial trauma
• Evidence of end-organ failure
• History of recent carcinoma (<5 year)
• Active smoker (>1 pack/day)
• Aged <18 or >60 year
• Documented abnormalities with facial mimetics and/or asymmetry (congenital, traumatic or acquired)
• Perforated nasal septum (cocaine abuse)

Abbreviations: EBV, Epstein–Barr virus; HLA, human leukocyte antigen; CMV, cytomegalovirus.

are required to have up-to-date upper and lower gastrointestinal endoscopy screening, in addition to computed tomography (CT) of the chest and abdomen/pelvis, and women older than 40 years must be current with screening mammography.

Comprehensive workup for the facial defect requires three-dimensional (3D) CT of the head and neck (Figure 89.2a through c), a life-size stereolithographic model, in addition to angiography (arterial and venous phase) (Figure 89.3a through c), sensory nerve testing (trigeminal nerve) and electromyography (facial nerve).

Videotaping and photographic documentation are crucial for assessment of the facial defect in addition to evaluation of mimetic and sphincter functions and speech.

Consultations to ophthalmology, dentistry, prosthodontics and otolaryngology are also undertaken at this stage.

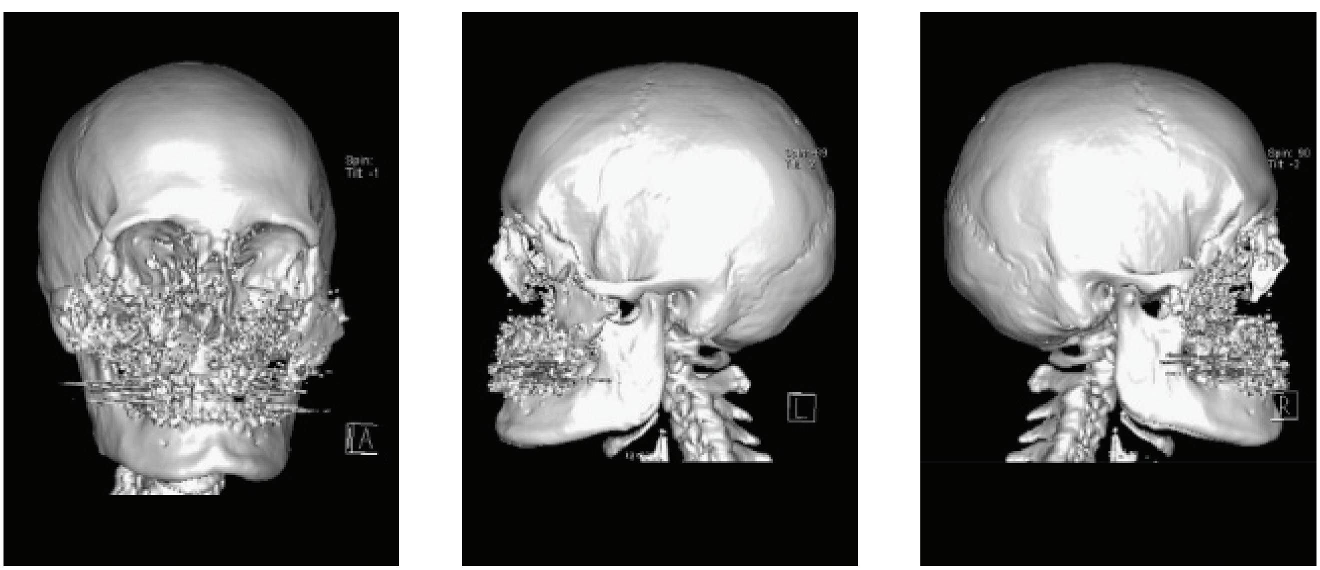
Dental impressions and splints, in addition to cephalometric analysis and virtual surgical planning might be needed to plan occlusion and maxillomandibular relationships if one or both jaws need to be transplanted.[1]

Planning

SOFT TISSUE AND BONE

Facial defects should be evaluated in three main domains:

- Soft-tissue deficiency as defined by facial aesthetic subunits.
- Functional compromise, e.g. oral competence and alimentation, eyelid mechanism and airway.
- Skeletal support and mucosal lining.



(a) (b) (c)

Figure 89.2 (a) Pre-operative three-dimensional (3D) computed tomography (CT) scan anterio-posterior (AP) view of the patient prior to face transplantation. Note the extensive and complex midface deformity. (b) Pre-operative 3D CT scan left lateral view of the patient prior to face transplantation. Note the extensive and complex midface deformity. (c) Pre-operative 3D CT scan right lateral view of the patient prior to face transplantation. Note the extensive and complex midface deformity. (Courtesy of the Cleveland Clinic.)

Figure 89.3 (a) CT angiogram of the right carotid artery and branches. (b) CT angiogram of the left carotid artery and branches. (c) Diagrammatic illustration of the vascular anatomy prior to transplantation. (Courtesy of the Cleveland Clinic.)

According to this assessment, a suitable matching allograft can be planned. Planning to maintain anatomical attachments between bone and soft tissue ensures a natural result and minimizes potential post-operative ptosis. A central deficiency could result in airway collapse and oral in-competence in addition to distortion in eyelid mechanism.[3]

BLOOD SUPPLY

3D CT angiography is essential to identify suitable recipient vessels, especially if previous procedures have exhausted available neck vessels (Figure 89.3a through c).

Precise determination of angiosomes is essential to avoid devascularizing intact parts of the face should the feeding artery be used as a recipient vessel (Figure 89.4).

Adequate perfusion is mandatory for success, by

- Minimizing bone resorption
- Ensuring viability and function of myoneural/neurosensory units
- Avoiding loss of teeth
- Preventing necrosis and resultant infections in an immunocompromised host

With increasing complexity of facial allografts including more and more skeletal elements, a concern emerged regarding the extent of skeletal perfusion by the facial artery. A recent anatomical study has shown the facial artery to consistently supply all facial bones with the exception of mandibular condyle, coronoid process and zygomatic arch. Perfusion is mainly provided by endosteal retrograde flow via anastomotic channels with the maxillary system especially at infra-orbital and mental foramina (osteotomies should be planned accordingly). At the same time, physiologic perfusion of teeth, nasal mucosa and maxillary sinus is preserved.[4] Clinical experience so far supports these findings.[5,6]

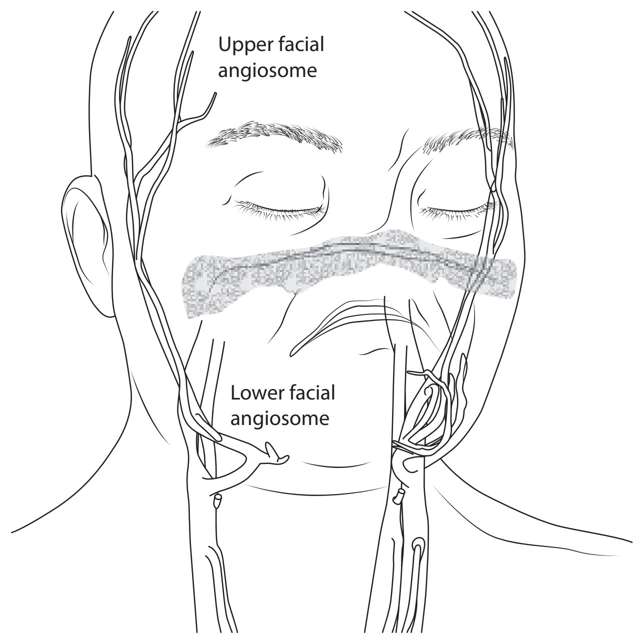


Figure 89.4 Diagrammatic illustration of facial angiosomes prior to transplantation. Note the face has been reduced to two angiosomes due to midface deficiency and scarring in addition to depletion of vessels following multiple prior surgical procedures. The upper face is irrigated by distal branches of the external carotid, while the lower face is only supplied from the left facial artery. (Courtesy of the Cleveland Clinic.)

Nerve supply

MOTOR

Recovery of facial expression, oral and eyelid competence is one of the most important functional goals of facial transplantation.

Multiple prior attempts at reconstruction can result in variable facial nerve injuries, and scarred perineural planes, rendering nerve identification and repair

challenging. Hence, detailed pre-operative neurologic exam, nerve conduction and electromyographic studies are essential to identify existing motor deficits. The length of allografted facial nerve should be tailored to the mimetic requirements of the defect, the existing facial motions and the functional needs of the patient.

Generally, the techniques reported either employ a proximal (main trunk) facial nerve coaptation or more distal (terminal branches) neurorrhaphies close to the target muscles.

More proximal repairs may result in more capacity of facial motion due to greater control of myoneural units. Distal repairs may result in more rapid recovery of motion and enhanced precision with less unpredictable motions and synkinesis.

Preservation of established myoneural units by fascicular mapping using a nerve stimulator, spares the patient post-operative functional loss.[7]

Nerve grafts should be harvested from the donor at the time of transplantation (e.g. the vagus, hypoglossal nerve) to allow tensionless neurorrhaphies in case of need.

SENSORY

Unlike motor nerves, sensory recovery has been observed without the need of sensory nerve re-coaptation between donor and recipient face.

Possible mechanisms for this include, trigeminofacial communications, afferent somatic fibres in the facial nerve and perivascular autonomic fibres. In addition, tacrolimus promotes nerve regeneration and reduces recovery time.[7,8]

Mock cadaver dissections

Unlike solid organ and limb transplantation where a predefined anatomic structure is approached in a consistent manner, face transplantation is tailored to a 3D defect that is unique to every patient. Thus, precise surgical planning and comprehensive preparation are absolutely essential for success. Mock cadaver dissections are finalized to facilitate the operative procedure and for an optimum outcome.[9]

TRANSPLANT PROCEDURE

Facial and solid organ transplant teams should have a clear set plan as to the sequence of organ procurement. Ethically, life-saving solid organ recovery generally takes priority over face or limb harvesting. However, face procurement is generally more complex and time consuming. Starting with organ or concomitant harvest may result in unacceptable facial graft ischemia time. Usually, face procurement is feasibly orchestrated as a first procedure without jeopardizing subsequent solid organ harvest by maintaining haemodynamic/autonomic stability of the donor throughout the process. It is mutually agreed that any sign of transgression in haemodynamic instability of the donor mandates interruption of facial harvest, and proceeding with solid organ procurement.

A preliminary tracheostomy secures the airway in the donor, as well as the recipient to facilitate surgical dissection, especially if a sizable composite facial allograft is planned.

Incisions are made to comply with aesthetic units and still provide the best possible access for safe dissection, osteotomies, osteosynthesis, vascular anastomosis and nerve coaptation.

Rigorous haemostasis is necessary for safe dissection and to ensure haemodynamic stability of the recipient.

Neck dissection is performed in a subplatysmal plane to identify and isolate the vascular pedicle (artery and vein) as well as to harvest nerve grafts (e.g. auriculotemporal, hypoglossal and vagus). Division of the sternocleidomastoid may improve exposure and facilitate dissection. In the recipient, dissection, mapping and tagging of preselected inflow and outflow vascular channels are undertaken by starting with identifying the great vessels in the lower neck and then proceeding distally. The facial nerve/branches can then be isolated either the main trunk as it exits the stylomastoid foramen or the branches at the anterior border of the parotid gland, after a superficial parotidectomy, if more distal neurorrhaphies are planned.

Mucosal incisions (oral, eyelid) are directly extended down to the periosteum to avoid disruption of ligaments and muscles maintaining soft-tissue/skeletal attachments to minimize post-operative ptosis and descent of the facial allograft.

Bony osteotomies can proceed after careful soft-tissue exposure for various osteotomy techniques (e.g. Monobloc, Le Forte III, Le Forte II, Le Forte I and bilateral sagittal split osteotomy [BSSO]) and should adhere to sound craniofacial principles to optimize outcome. Donor enucleation may be necessary to facilitate periorbital osteotomies. If both jaws are to be transplanted, to maintain occlusion maxillo-mandibular fixation (MMF) should be performed.

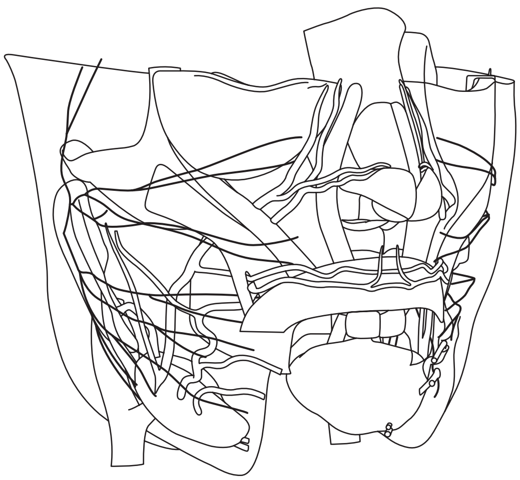
If the procurement of the donor is undertaken in proximity to the recipient, a careful coordination of timing of dissections between donor and recipient teams can be performed with direct communication. Before final allograft disconnection and deliverance, the donor team should ensure that the recipient is ready for inset to minimize ischemia time.

Once ready, the facial allograft is disconnected and insetting to the recipient can start (Figure 89.5a through c).

First, skeletal fixations are performed at selected points to afford preliminary bony fixation that is stable enough to allow safe microvascular anastomosis and decrease warm ischemia. Additional skeletal fixation to enhance rigidity can be accomplished later once flap perfusion is ensured (Figure 89.6a through c).

Arterial and venous anastomosis is undertaken unilaterally on the side judged to be easier and more favourable, again to minimize warm ischemia time. Contralateral anastomosis would follow once the perfusion from first anastomosis is established.

(a)



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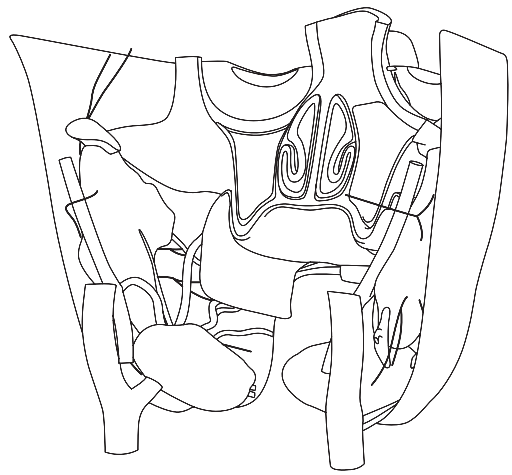


(c)

Figure 89.5 (a) The harvested face graft. (b) Diagrammatic illustration of the components of the face transplant. Front perspective. (c) Diagrammatic illustration of the components of the face transplant. Back perspective. (Courtesy of the Cleveland Clinic.)

The next crucial task is facial nerve neurorraphy. Interpositional nerve grafts might be used to achieve tensionless neurorrhaphies. Sensory nerve coaptations can then follow if feasible. The facial allograft is then closed in layers from deep to superficial starting with the mucosal layers, muscle repair, subcutaneous layer and finally skin.[1,10] Expected oedema has to be taken into account by avoiding tight skin closure (Figure 89.7a through c).

POST-TRANSPLANT PHASE

The composite vascularized facial allograft is monitored post-operatively in the ICU setting with hourly clinical examination for colour, temperature, oedema, fullness along with arterial and venous Doppler signals.

Normalization of haemodynamics, electrolytes, acid–base balance, oxygen saturation and carbohydrate levels is paramount. Monitoring of circulatory, respiratory, neurological, renal and liver functions ensures timely pre-emptive medical interventions to minimize adverse events. Nutritional assessment and management is valuable at this point to meet the hyper-catabolic response following this type of surgery.

The immunosuppressive regimen usually includes thymoglobulin for induction, and standard triple-therapy including tacrolimus, mycophenolate mofetil and prednisone.

Rejection screening is accomplished according to a predefined protocol and includes punch biopsies from the skin and mucous membrane every 72 hours for the first 2 weeks, then every week for the first 3 months and then once a month for the first year. An experienced pathologist evaluates the specimens by using a consistent rejection scale as the Banff classification.

Intense physical therapy, sensory re-education and speech therapy are started 48 hours after surgery and continued daily for 6–8 weeks and then decreased to three times per week. Regular assessment of facial expression, swallowing, mastication and speech is essential to monitor progress. Serial photography/videography in addition

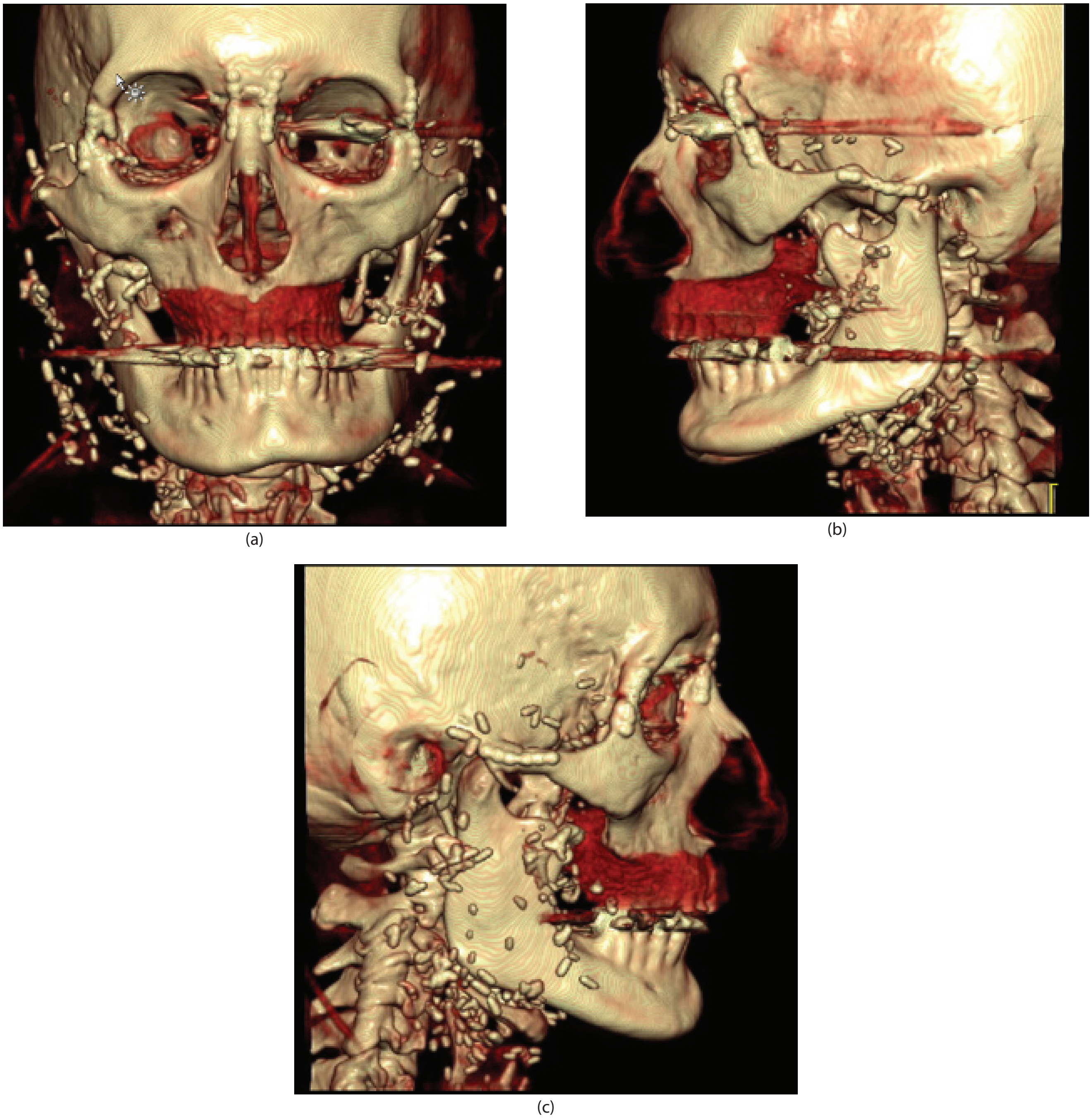


Figure 89.6 (a) 3D CT scan of the facial skeleton AP view after transplantation. Note the adequate skeletal relationships of the hybrid skeleton. (b) 3D CT scan of the facial skeleton left lateral view after transplantation. Note the adequate skeletal relationships of the hybrid skeleton. (c) 3D CT scan of the facial skeleton right lateral view after transplantation. Note the adequate skeletal relationships of the hybrid skeleton. (Courtesy of the Cleveland Clinic.)

to nerve conduction and electromyographic studies serve for documentation and regular assessment.

Sensory testing (Tinel sign, Weber static two-point discrimination and Semmes–Weinstein monofilament technique) for supra-orbital, infra-orbital and mental nerve zones is performed regularly.

Psychological support daily for 6–8 weeks, and then three times per week is important to manage the psychosocial challenges following transplantation.[1]

OUTCOME

Immunologic outcome

Acute rejection is most common in the first year. Reversal is usual with increasing steroid or tacrolimus dose, in addition to topical steroid or tacrolimus adjuncts (Figure 89.8a through c).

No hyperacute rejection has been reported so far.

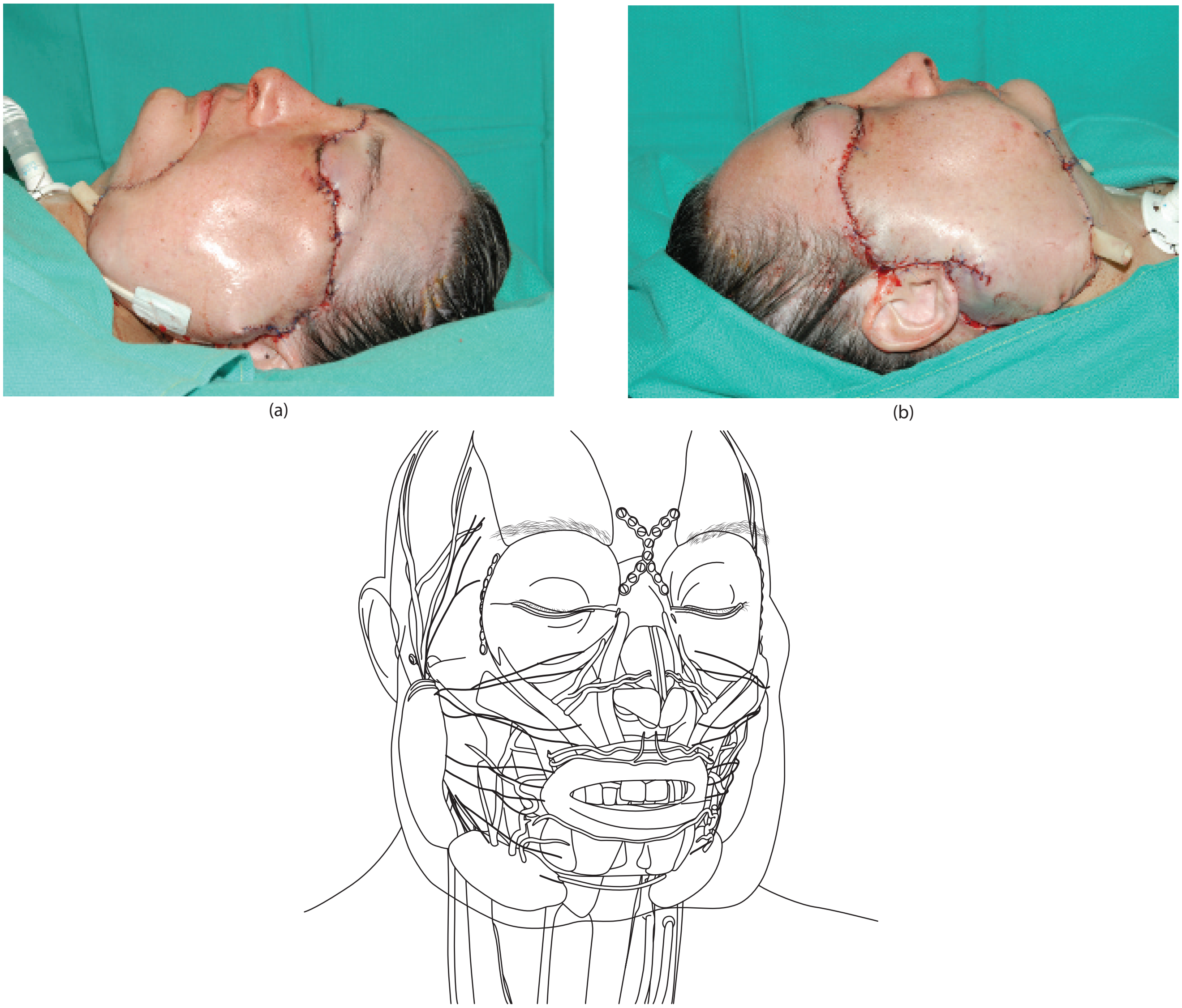


Figure 89.7 (a) Intra-operative left lateral view following inset of the facial transplant. (b) Intra-operative right lateral view following inset of the facial transplant. (c) Diagrammatic illustration of face transplant after inset. (Courtesy of the Cleveland Clinic.)

Infections are common. CMV donor/recipient mismatch predisposes to life-threatening infections and can trigger acute rejection. Many transplant teams, therefore, avoid CMV mismatched transplantations.

Despite adequate prophylaxis for CMV (ganciclovir and valganciclovir), herpes simplex (acyclovir) and *Pneumocystis jirovecii* (trimethoprim-sulfamethoxazole), many patients developed opportunistic infections including CMV activation, herpes simplex, herpes zoster, EBV, Candida, rosacea, staphylococcal, Enterobacter and *Pseudomonas aeruginosa* infections.

Monoclonal B-cell lymphoma has been observed in one EBV mismatched patient, and tumour recurrence in an HIV-positive patient resulted in death.[7]

Functional outcome

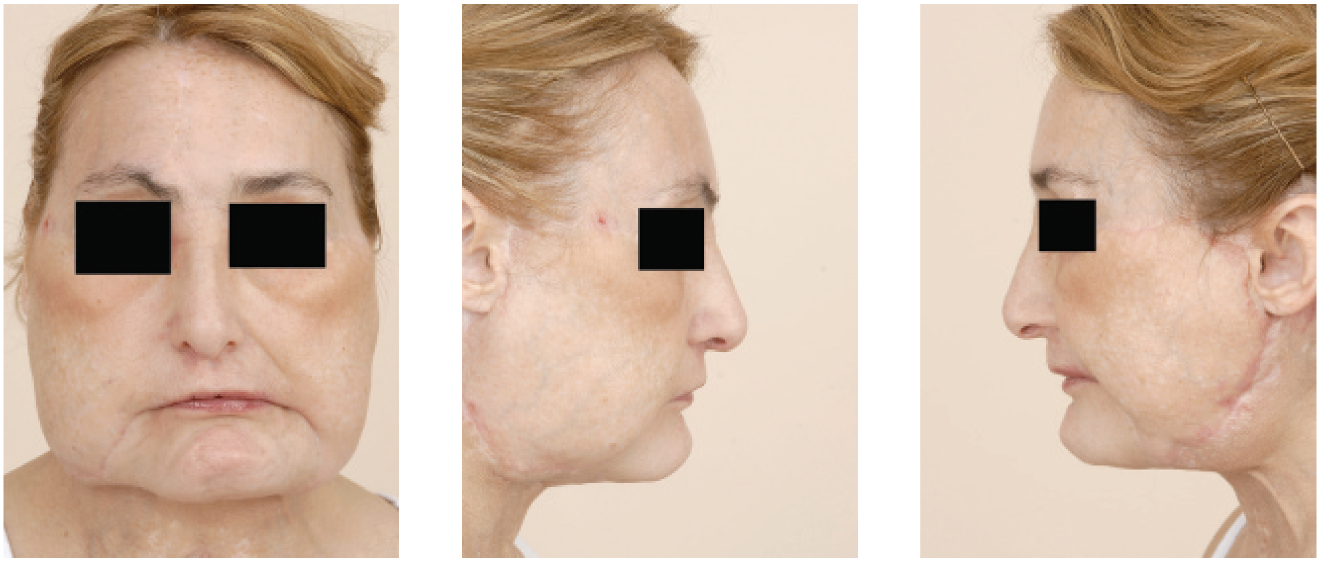
Sensory appreciation in the graft usually occurs even in absence of sensory neurorrhaphy but may be delayed up to 6 months.

Motor recovery, however, is dependent upon facial nerve repair and may take up to 6 months for lip closure, 8 months for complete mouth occlusion and 2 years for smile. Improvements usually continue over time.

Thus, ability to eat, drink, speak, smell and smile has been reported in almost all patients.

Significant reduction in chronic pain following excision of scarred tissue and release of contractures has been reported as well.

Optimum outcomes require intensive physical, speech and psychological rehabilitation.[7]



(a) (b) (c)

Figure 89.8 (a) Frontal view of patient 4 years following face transplant. Note the midface restoration and tracheostomy independence. (b) Right lateral view of patient 4 years following face transplantation. Note the midface restoration and tracheostomy independence. (c) Left lateral view of patient 4 years following face transplantation. Note the midface restoration and tracheostomy independence. (Courtesy of the Cleveland Clinic.)

Psychological outcomes

Face transplantation has had a favourable psychological impact in the majority of patients with decreased depression, improved self-image, adequate social integration and work resumption.[7]

COMPLICATIONS[11,12]

Table 89.3 Complications

- Bleeding (requiring transfusions up to 66 units of packed red cells)
- Jugular vein thrombosis
- Insulin-dependent new-onset diabetes mellitus
- Transient thrombocytosis
- Acute renal failure
- Thrombotic micro-angiopathy
- Transient steroid induced confusion
- Transient leukopenia
- Post-transplantation monoclonal B-cell lymphoma
- Cervical dysplasia
- Severe rhabdomyolysis
- Acute respiratory distress syndrome
- Right diaphragmatic paralysis
- Rosacea
- Bacterial infection
- CMV infection
- Herpes virus infection
- EBV
- Molloscum contagiosum

Abbreviations: EBV, Epstein–Barr virus; CMV, cytomegalovirus.

MORTALITY

Three mortalities have been reported so far (mortality rate: 11.1%). Two patients were lost following acute rejection due to failure of compliance with immunosuppression (China) and secondary squamous cell carcinoma of the hypopharynx (Spain). One patient died following combined face and double-hand allotransplantation due to sepsis resulting from pseudomonal graft infection (France) (Table 89.3).[12]

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